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AND ABSTRACT OF THE LITERATURE

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Health Hazards in the Cotton Industry
(*To be continued*)

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A Simple Face Mask for Certain Types of Dusty Industrial Processes

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HEALTH HAZARDS IN THE COTTON INDUSTRY*

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HEALTH OF COTTON OPERATIVES

PRELIMINARY to discussing details of the various health risks presented by the different branches of the cotton industry, it is essential to provide some definite information respecting the particular diseases which manifest a selective quality among the several groups of operatives concerned. Although an intimate acquaintanceship with the industry for nearly forty years may have produced "proof as strong as holy writ" so far as concerns my own convictions as to their nature and causation, I must acknowledge that there are many difficulties in the way of producing a sufficiency of solid evidence to prove the correctness of my beliefs to others. There is evidence, of course, but it has concern mainly, though fortunately not entirely, with the industry as a whole, whereas, as I am going to show later on, the predominant illnesses vary with the different branches.

With regard to mortality figures, the returns of the Registrar-General for the years 1910, 1911, 1912 include, for the first time, particulars respecting strippers and blowing room operatives (1), but the other branches still lie buried in the common grave of the all-in table and cannot be dug out. One might look to medical officers of health for some assistance, but although they are particularly plentiful in Lancashire, the only series among their annual reports which gives special details of what different groups of cotton operatives die from locally comes from Blackburn. These reports are really valuable, and have been of great

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service to the weaving division of the industry. If the medical officers of health of some of the spinning towns had followed so excellent a lead, our present knowledge of the selectivity of fatal diseases would have been much more extensive than it is; and in saying this I am taking into account that the Blackburn statistics, unlike the Registrar-General's figures, refer to females as well as to males.

Mortality figures, however, are not all-sufficient for my purpose. There are many nonfatal ailments causing considerable loss of time to the worker, as well as serious diseases which may occur once or many times without any of them proving to be the ultimate cause of death, the incidence of which must be taken into account when considering the influence exercised by trade processes on bodily health. It is therefore essential that morbidity statistics should have their place by the side of mortality figures if ultimate conclusions are to earn the hall mark of reliability. Knowing that the Cotton Operatives' Unions have their own approved societies for health insurance, I naturally turned to these for information, but only to find that their locker was empty. On the whole, these bodies seem to be so much taken up with the financial aspect of national health insurance that the actual diseases giving rise to the demands for sick pay have not so far been able to impress their real importance upon the minds of those responsible for direction. Fortunately, however, through the kindness of the Secretary of the Card and Blowing Room Operatives' Approved Society, I have been able to obtain sufficient material for the compilation of a very complete sickness table.

Although available information is so incomplete, I nevertheless think I shall be able to show, from such data as I have collected, to what diseases and ailments the operatives generally are specially susceptible and, in some measure, how unequally certain illnesses attack particular groups.

In dealing with mortality statistics I have found it convenient in the first place to put together a composite table from details abstracted from the Registrar-General's occupational mortality figures (1) (see Table 1). The table covers all the ground that can be covered by this official publication and certainly makes a number of points quite clear. It shows that, although the general occupational mortality figure has diminished to a marked degree, the cotton mortality figure has dropped in a still more phenomenal manner, the points between the two periods 1900 to 1902 and 1910 to 1912 being 303 in favor of the latter against 214; that the diminution has particularly affected diseases classified under nervous, respiratory, and circulatory headings, and also tuberculosis; that cotton operatives still suffer more than other textile workers, and more than occupied and retired males generally, from bronchitis and from "other circulatory diseases;" that strippers and grinders and blowing room operatives suffer from these diseases, from pneumonia, and from tuberculosis much more than do cotton operatives generally, though there is no indication of the relative position of the spinner or weaver; that a larger proportion of blowing

room operatives than of strippers die from nervous diseases but that the positions are reversed with respiratory diseases; that the cotton operative generally has no particular predisposition to tuberculosis; and that the blowing room hand is the only cotton operative who dies from diseases of the digestive system more than does the average worker. Since it is common knowledge that the cotton towns are severely afflicted with atmospheric smoke pollution and that this factor influences the local respiratory death rate, it might be considered reasonable to assign the excessive mortality of cotton operatives from this type of disease to such a causation. Undoubtedly this atmospheric pollution must affect cotton operatives as it does the rest of the population, but as the former die from respiratory disease at a greater rate than the latter there must be some other factor exercising a noxious influence. That this is so is shown by engineers in Lancashire towns who live under the same domestic conditions as cotton operatives and have practically the same general mortality figure, but a respiratory

TABLE 1.—SELECTED OCCUPATIONAL MORTALITY FIGURES (MALES)[1]

CAUSE OF DEATH	COTTON OPERATIVES		1910-12			ALL OCCUPIED AND RETIRED MALES	
	1900–02	1910–12	Strippers and Grinders	Blowing Room Operatives	Other Textile Workers	1900–02	1910–12
Phthisis	197	120	155	136	128	187	142
Other tuberculous diseases	.....	13	25	18	13	.....	10
Cancer	72	71	59	85	80	68	78
Diabetes	11	10	8	12	11	10	10
Alcoholism	12	3	.....	.....	3	16	4
Nervous diseases	128	94	72	109	91	103	85
Valvular heart disease	36	38	34	47	39	36	39
Other circulatory diseases	134	96	140	105	88	110	79
Bronchitis	92	57	150	126	47	58	38
Pneumonia	109	70	113	87	63	92	67
Other respiratory diseases	24	15	20	47	14	27	15
Cirrhosis of liver	17	11	6	12	11	27	13
Other digestive diseases	32	33	6	43	39	27	34
Bright's disease	38	48	37	51	49	35	39
Other diseases of urinary tract	23	8	16	8	8	17	9
Suicide	20	22	6	67	22	19	19
Other causes	169	102	141	137	95	172	109
General mortality figure	1,114	811	988	1,090	801	1,004	790

[1]The figures represent the number of deaths that would have occurred if the occupational death rate from the causes given had been operating upon a standard male population between the ages 25 and 65 which at the rates prevailing during the period 1900–02 produced 1,000 deaths. This standard population figure is 71,005.

mortality figure of only 113 against 142 for cotton operatives generally and 283 for strippers and grinders.

I have to turn to the Blackburn tables to make out my case for the weaver. Dr. Greenwood (2) dealt with three successive five-year periods between January, 1891, and December, 1905, and was able to demonstrate some very marked diminutions in death rates between the first and the later periods. During the period 1891 to 1895 the death rate from respiratory diseases for the age group 55 to 65 was 16.5, and for the age group 65 and upward it was 65.6; the rates for 1901 to 1905 had dropped to 10.7 and 17.6, respectively, and for all age groups combined were below that of the town. The phthisis rate was above the town rate for the second period, but at the same figure for the first and third periods. Dr. Daley's figures (3), published in his annual report for 1923, show further improvement, the non-tuberculous respiratory rate being reduced to below that for the town, and the phthisis rate also, but to a less degree. They certainly convey the impression that weaving may now be considered as quite a healthful occupation, and particularly so in the case of women. Female occupational death rates must, however, be regarded as subject to heavy discounting. A curious feature respecting the health of the Blackburn weavers is that the improvement set in almost immediately after the passing of the Cotton Cloth Factories Act of 1889.

The only morbidity figures of any value in England are those which I mentioned as being compiled by myself from the records of the Card and Blowing Room Operatives' Approved Society. I examined details of 10,548 cases of sickness which caused absence from work during a period of two years extending from July 1, 1922, to June 30, 1924, and placed them under what I consider to be useful headings (see Table 2). The males are strippers and blowing room men and cotton room men; the females work as card tenters and to some extent as blowing room hands, but mainly as frame tenters and as ring spinners and doffers. The men and some of the women are subjected to excessive dust and the majority of the women and girls work in an atmosphere which is often too hot, frequently contains too much moisture, and on the whole is very similar to what one finds in mule spinning rooms.

Table 2 shows that both sexes suffer excessively from bronchitis, influenza and colds, rheumatic affections, and digestive troubles; that males suffer more than females from chest disease; that females suffer more than males from diseases produced by catching cold, from anemia, digestive troubles, and nervous affections. The phthisis rate is particularly small for both sexes. During the year ending June, 1924, female members to the number of 1,431 received maternity benefit, and of this number only six lost their lives as a result of childbirth. In this same period only two miscarriages were recorded, and only two or three absences which could be assigned to functional menstrual trouble.

I obtained from the respective secretaries some particulars in regard to time lost through sickness by members of all three Approved Societies connected with the cotton industry and it is interesting to compare the

figures (Table 3). It seems curious that the male spinners should lose the least time and that the female spinners should lose the most time from sickness. The explanation for the latter appears to be that female mule spinning operatives are away from work for a longer period before confinement than are the females in the other two groups, and claim sickness benefit on the ground that their condition does not allow them to work at their trade though it permits them to do housework.

To sum up the whole position, it may be said that the figures quoted

TABLE 2.—SICKNESS INCIDENCE PER 1,000 MEMBERS OF CARD AND BLOWING ROOM OPERATIVES' SOCIETY, JULY 1, 1922, TO JUNE 30, 1924

ILLNESS	MALES	FEMALES
Injury (not due to employment)	10.61	7.54
Septic poisoning	1.94	3.15
Anemia	0.71	11.97
Apoplexy	0.44	0.03
Appendicitis and peritonitis	1.30	1.55
Bladder disease	0.34	1.17
Bronchitis	29.33	17.32
Cancer	0.14	0.14
Diabetes	0.21	0.08
Diseases of eyes and ears	2.59	2.43
Hemorrhoids	0.93	0.45
Diseases of heart and blood vessels	5.76	5.05
Hernia	0.93	0.48
Infectious disease	1.07	1.10
Influenza and colds	26.79	39.14
Diseases of kidneys	1.59	0.68
Diseases of liver	0.36	0.07
Diseases of nervous system	6.27	8.27
Diseases of nose	0.51	0.47
Phthisis	1.43	1.33
Pneumonia and pleurisy	4.75	2.65
Rheumatic affections	11.53	12.48
Diseases of sexual organs	0.79	8.97
Diseases of skin (including ulceration)	7.41	6.02
Diseases of stomach and intestines	11.53	16.68
Tonsillitis and quinsy	5.11	12.15
Tuberculous disease of joints, glands, skin, meninges, etc.	0.25	0.96
Other illnesses	8.73	5.81
Number of cases	1,989	8,559

TABLE 3.—NUMBER OF DAYS OF SICKNESS PER MEMBER PER ANNUM (1923) RECORDED BY THREE APPROVED SOCIETIES OF COTTON INDUSTRY

SOCIETY	MALES	FEMALES
Card and Blowing Room Operatives	9.8	10.8
Operative Spinners	8.0	14.0
Weavers, Winders, and Warpers	9.8	12.6

show that bodily health is steadily improving among all classes of cotton operatives but that the various branches of the industry still exhibit a definite partiality for particular diseases and ailments.

Conditions Affecting Health of Operatives

Having adopted certain definite conclusions concerning the diseases and ailments to which operatives in the cotton industry are particularly liable, the next step is to consider the various factors which can be shown to account for the excessive and selective susceptibility.

Temperature and Humidity

The successive processes to which cotton is submitted in the course of conversion from vegetable down to plain cotton cloth demand for their successful exploitation certain definite atmospheric qualities. As the processes are operated under control by and with certain assistance from the human element, man and machine thus working together in the same defined space, it would appear essential to perfection of production that these atmospheric qualities should be so maneuvered that they may be equally satisfactory to both factors. Considerable headway has been made in this direction since the close of the last century, but there are still difficulties to overcome before the ideal relationship is reached. I am satisfied, however, that the proposition is both practical and practicable, and my subsequent explanations and observations will, I have no doubt, fully support this optimistic statement.

In dealing with the influence exercised by temperature and humidity in cotton manufacturing processes, I propose to treat the subject in the first place from the cotton point of view, and afterward from the human aspect; I will then endeavor to show where the two interests conflict and what can be done to bring them into common line.

Cotton Point of View

Being a native of the County Palatine, and endowed with a proper local patriotism, I must necessarily commence this part of the story by explaining how it comes about that the climatic conditions in Lancashire are so favorable to cotton manufacture.

Geographically the cotton towns and their surroundings occupy a dished-out area, in the southeast of the County, which is sheltered by the Pennine Chain to the east and north, and by the Derbyshire Hills to the south; only the west is open, and in that direction the land extends as a level plain to the sandy shores of the Irish Sea. There is thus ample protection from cold, dry winds and an open door to the temperate, moisture laden breezes from over the water. The climate of this particular district is therefore temperate, equable, and moist. The high percentage of moisture is due to the cooling influence of the hills on the warmer air of the plain, relative humidity automatically increasing in proportion to temperature lost. The temperature of Blackburn is ordinarily about 2° less than that of Liverpool but the humidity figure averages more than that of Liverpool by rather over 8 per cent. The same conditions

which produce a higher percentage of humidity increase the rainfall, but of health for the various cities and boroughs quoted, illustrates the points

TABLE 4.—LOCAL RELATIVE HUMIDITIES, 1924

PLACE	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	AVERAGE	MEAN VARIATION
	%	%	%	%	%	%	%	%	%	%	%	%	%	
Liverpool..	87.0	83.0	73.0	79.0	79.0	76.0	74.0	80.0	70.0	82.0	85.0	86.0	79.5	3.9
Bolton.....	93.4	86.9	80.0	82.1	80.3	80.2	77.5	73.1	79.8	83.9	86.7	93.7	84.0	5.1
Blackburn.	91.8	86.58	89.03	85.0	84.54	83.2	82.8	86.8	87.73	86.45	80.58	93.3	87.23	2.9
Oldham....	84.0	87.25	85.4	78.5	79.0	...	...	80.0	76.75	80.25	81.4	78.75	...	..
Manchester	89.0	86.0	79.0	82.0	81.0	76.0	75.0	84.0	79.0	81.0	84.0	88.0	82.0	3.5
Halifax....	76.0	91.0	91.0	92.0	79.0	93.0	87.0	86.0	86.0	86.0	92.0	85.0	87.0	4.0
Leeds.....	86.26	84.21	80.75	77.26	78.96	72.77	75.29	76.75	78.73	82.68	85.98	87.26	80.69	4.0
Coventry..	88.0	85.0	79.0	73.0	74.0	72.0	68.0	79.0	80.0	77.0	95.0	91.0	81.0	6.6
Birmingham.....	89.9	85.0	75.6	76.0	79.5	77.6	75.6	80.6	83.6	88.6	85.6	88.5	82.0	4.7
Norwich...	91.0	86.0	78.0	70.0	76.0	71.0	73.0	81.0	83.0	89.0	87.0	90.0	81.0	6.2

there is no closer relationship between the two.

Both spinning and weaving processes flourish best where there is little variation in atmospheric conditions, but the latter processes require a higher relative humidity. It is therefore interesting to note that, in the natural selection of sites, fine spinning should settle where hill and plain meet, as in Manchester and Bolton, that coarser spinning should select the foothills, as in the case of Oldham, Middleton, Ashton, etc., and that plain calico weaving should have chosen its site, even before the mechanical age, among the sheltering hills of Blackburn and Darwin. With regard to humidity, it is important to note that it is the percentage at any given temperature which matters to the cotton industry and not the actual amount of moisture. Table 4, compiled from information kindly supplied by the medical officers mentioned. The figures are for the year 1924, which was not particularly bright and sunny.

The high percentage of humidity at Blackburn which lies well within the shelter in the hills, and the very little variation from month to month, are very clearly shown. Other points made plain are the greater mean variations on the Yorkshire side of the Pennine Chain and in the more open towns of Norwich and Coventry. The Liverpool figures illustrate the great change wrought in atmospheric qualities by the alteration in the configuration of the land surface only a few miles away. It is unfortunate that the Oldham figures should be incomplete and thus lose their comparative value; the mean variation there would otherwise work out probably at about 3. The Bolton figures have apparently suffered through fog.

That these unique climatic condi-

tions should not lose their beneficial qualities with the advent of power machines is well understood when it is realized that the natural and equable humidity is sufficient, in most cases, to cover the reduction due to the increased temperature of factories brought about by concentration of moving machinery, and that in those factories where artificial assistance is required the difficulties in applying it are more readily overcome.

Spinning.—Under modern conditions the process of spinning requires a high temperature which must be maintained as nearly as possible at one level throughout the year, owing to the fact that the individual fibers are rendered more pliable and thus easier to spin when their waxy content is softened by heat. The wax melts at about 80°F. The actual temperature of a spinning room should be ruled by the class of counts going through at the time, and it may be stated broadly that effective temperatures range from 70° to 80°F. for coarse counts, between 80° and 85°F. for medium counts, and between 85° and 90°F. for fine counts. Steam pipes are invariably fitted in the rooms for heating purposes, though it is only necessary to use them occasionally in the early morning, often only at the beginning of the week, and more regularly during the colder months of the year. The friction caused by rapidly moving machinery is the normal source of heat, and the temperature so produced must be regulated to the required degree by ventilation. Where the lower counts are spun, this ventilation is mostly effected by having glazed swinging panels, or hopper, fixed in all or a considerable proportion of the windows; in some mills this system is augmented by propulsion or extraction fans. In modern fine spinning rooms it is now customary to install a complete filtering, ventilating, and humidifying plant.

The demand for humidity as an aid to spinning is not a heavy one, but a certain amount is required and must be kept at an even percentage, the actual figure again bearing a direct relation to the counts going through. Dry air makes the fibers brittle, causes breakages, interferes with the twisting properties of the fibers, and produces a less uniform and a weaker yarn. When the degree of moisture is insufficient, the cotton becomes electrified by its rapid passage over metallic surfaces, and this causes the individual fibers to repel one another and so to interfere with their proper and regular twisting; the result is an irregular, spongy, and weak yarn. A relative humidity of 40 to 50 per cent. is sufficient to prevent the generation of this electricity. There is a limit, however, to the effective amount of moisture. In fine spinning rooms, where accurate records are kept, it is found that a higher percentage than 50 interferes with the drawing out of the roving and causes it to cling and wrap round the delivery rollers. The rovings for coarser counts are thicker and will therefore tolerate more moisture without this happening. For fine counts a relative humidity of about 45 per cent. is found the most suitable in practice; for most medium counts the humidity does not need to exceed 50 per cent. In view of this Lancashire experience, it is perhaps surprising to find some foreign experts making a broad statement that fine counts require more humidity than

those of the coarser variety. A well-known quality of humidity is its power to increase the tensile strength of the yarn so that theoretically this may be true, but I am confidently assured by a very experienced manager that his adoption of a humidity approaching 60 per cent. would quickly result in a deputation from the spinners.

Coarse counts are spun from cotton of lower quality and shorter staple and get their stability from the thickness of the yarn, but, as the draw is longer and the speed quicker, it is easy to understand in their case that an increase in tensile strength from greater absorption of moisture will enable the rovings to be drawn to the requisite fineness with less breakages, and, as has been stated, without blocking the delivery rollers. A humidity of 60 to 65 per cent. for counts of this type may be regarded as a limit for the production of a good and sufficient tensile strength but the actual amount of humidity used depends mainly on the quality of cotton and often on the prejudice of the manager. In ring spinning, the strain on the drawn-out roving is much less than is the case with mule spinning owing to the short distance between the draft rollers and the spindle, so that less strengthening, and therefore less humidity, is required. In Lancashire the atmospheric humidity, modified by the increased temperature of the spinning room, is usually sufficient throughout the year for coarse counts, whatever the process.

The amount of humidity can be regulated to a nicety, in spite of weather or season, where complete systems for filtering, humidifying, cooling, and heating the air are utilized. These installations are now regarded as a necessity to fine spinning, as it takes several days to fill the cops and the yarn must be kept clean during the process. Wet and dry bulb hygrometers are hung in the rooms and the atmosphere is regulated according to their indications. Those mills which depend on natural ventilation often require additional humidity during hot and dry weather, particularly when there is an easterly wind blowing. Water troughs and trays, as well as watering cans on occasion, are still used, but the modern practice is to have several water spray apparatus fitted, and to use them separately or in combination whenever required. A spinner soon knows when humidity is needed.

Preliminary Processes.—In the preliminary processes of opening, scutching, and carding, natural atmosphere, as modified by frictional heat, is usually sufficient in Lancashire, except during cold weather when the rooms are heated before commencing work. Card rooms, which include within their limits the processes of drawing, combing, and roving, have an ordinary working temperature of from 70° to 75°F., though some mills start work at much less than this without detriment; even in July 80°F. is very rarely exceeded. In some observations of my own made in Manchester during the summer of 1925, the mean of both morning and afternoon temperatures was 79.3°F. and the mean humidity 51.6 per cent. My investigations indicate that if the humidity is below 40 per cent. there is risk of electrification, but that anything between this percentage and 55 or 60 per cent. may be regarded as effective.

How the Manchester climate meets the humidity demand is easily demonstrated. A mean outside July atmosphere in Manchester containing 4.4 grains of water to the cubic foot produces a relative humidity of 75 per cent. at 60°F. (dry bulb), but when the air is heated up to the factory temperature of 79° this percentage is reduced to 42; if, however, one takes into account the possibility that the moisture evaporated from the workers may add another 0.7 grains to the cubic foot, the humidity of 51.6 per cent. at 79.3°F. quoted above as an inside mean for this month is accounted for. There are some firms, however, who deem it necessary to fix humidifiers, and I know mills which have complete conditioning plants. It is usual to find card and blowing rooms freely ventilated by open windows; extraction fans are frequently used, sometimes propeller fans, and either variety may be fitted, with or without ducts. In other countries, owing to climate, artificial moisture has to be introduced into these preliminary processes, and in India, during the monsoon, the natural humidity is so excessive that steam heat is frequently utilized in the card rooms to lower the percentage. Artificial humidity is not much required in the more humid provinces of Calcutta, Madras, and Bombay, and when used is mainly for cooling purposes and in the form of atomizers or wet hanging mats. In the dry climates of Ahmedabad, Cawnpore, and the Central Provinces, artificial humidification is in general use except during the monsoon (4).

Subsidiary Processes.—Doubling of yarn is carried on under conditions of high temperature similar to those which obtain in spinning, and the heat may be very trying in the summer time. As the practice of driving the frames directly by electric motors is now becoming very general, an additional source of heat is being provided and at the same time air movement from running straps and pulleys is being diminished. This circumstance means a greater call on ventilation, and in my experience employers seem to be meeting this fairly well. Plenum fans, some with air filtration arrangements, extraction fans—drawing air direct from the room or through a metal duct fitted with spaced inlets—and cross ventilation from open windows are all extensively utilized. As should be explained, the common practice is to run the threads through water before twisting so that no question of artificial humidification arises. In dry doubling, atmospheric conditions are sufficient.

Natural atmosphere, with the addition of steam pipes for warming when necessary, and windows to open meet the necessary requirements for winding, reeling, beaming, and warping, though other countries appear to require artificial humidity for the two first named. In gassing rooms the temperature is apt to be high, but this is an effect, not a requirement, of the process.

Weaving.—In the early days of weaving cotton cloth by hand loom, high temperature was unattainable, owing to the segregation of looms and the slow speed at which the process was carried on. Humidity was, however, an important item, and a damp outbuilding or half cellar was considered by the weaver to be a good asset. The advent of the mechani-

cal loom, with the concentration of large numbers of these machines under one roof and the increased speed at which they were driven, brought about the first change in the requirements for efficient weaving. A higher temperature in the weaving space was a natural sequence, and this was found to be beneficial by preventing breakages; the percentage of humidity was lowered but, being aided by evaporation from the workers and the nature of the site usually selected, was found to be sufficient.

The second change in requirements was brought into effect by the demand from Eastern markets for a very cheap type of cotton cloth. To provide this at a profit meant high speed of production and loading up the yarn with foreign material to give it weight and appearance. The friction of the shuttle and the reed against the warp at high speeds has a tendency to produce electrification of the warp threads, which interferes with their passage between the reed wires and causes frequent breakages and flying shuttles. As I have previously explained, a sufficient humidification neutralizes electrification and increases the tensile strength of the yarn; it is also the cheapest method of keeping down dust and of rendering the heavily sized warp workable in the looms. The natural humidity was therefore increased by artificial means in sheds weaving goods of the type described, the earliest and, for a considerable time, the only method utilized being the introduction of raw steam. These factories are known as "wet" sheds, in contradistinction to factories where artificial humidity is not required and which are styled "dry" sheds.

Dry sheds, according to Lander (5, p. 39), are in the proportion of about 61 per cent. in England, and their function is to produce the better quality and more elaborate varieties of cotton cloths and particularly those containing dyed yarns. Looms are run at a less speed, the yarn is stronger, and any sizing used is of a simple character and in small bulk, so that the usual reasons for extra humidity do not exist. The temperature ranges from 60° to 70°F., except in the early morning when it may be down to 50°F., or on a hot summer's day when it may reach 80°. The winter morning temperature can be suitably rectified by warming pipes, and any tendency to excessive heat in summer by free ventilation. The latter has improved since a standard of air purity was fixed for this class of shed in the Regulations of 1911. Roof cowls, hinged skylights and fanlights, spaces beneath the eaves, wall inlets, propeller fans, and extractors are mentioned in the 1902 Report of the Departmental Committee on Ventilation of Factories and Workshops (6) as being in ordinary use.

Wet sheds present a more difficult problem than the dry sheds. With regard to temperature, Lander (5, p. 40) states that 70°F. is the most suitable for weaving purposes, and from the numerous shed records I have examined it would certainly appear that this need not be exceeded for efficient working in England. It is apt to be higher in the summer time, but in the winter it is frequently lower. In practice, however, high temperatures are, to a large extent, the result of demands for a high percentage of

humidity and the utilization of steam; this was particularly exemplified in the days when raw steam issuing from unlagged pipes was the sole method of providing this humidity. It is now generally agreed, according to Lander, that an average humidity of 76 per cent. is a reasonable amount for materials commonly woven in humid sheds, and this was evidently the view when the scale in the existing Regulations was adopted, for at this percentage the temperature cannot exceed 78° and must come lower if the humidity percentage is to be further increased. The extreme limit of wet bulb temperature at which humidifying must cease is 75°, and this is equivalent to only 75 per cent. of moisture at the corresponding dry bulb scale temperature of 80°. Nevertheless, there is plenty of room for varying the humidity within the prescribed limits and there appears to be no doubt that it is often present in excess of the actual needs. For example, it was shown by the Departmental Committee on Humidity and Ventilation in Cotton Weaving Sheds (7) that heavily sized cloth (70 per cent. to 260 per cent.) was being regularly woven with a daily average of 73 per cent. of humidification, while lightly sized material was being subjected to a daily average of 76 per cent. These figures certainly give the impression either that the lightly sized goods have been subjected to excessive humidification or that the very general view that heavily sized cloth requires high humidity is wrong. On the other hand, the popular view that efficiency of process in humid sheds, within certain limits, increases as the temperature or the relative humidity increases is supported by Wyatt's investigations (8), published in 1923, which tend to show that output varies directly as the product of the two. He concludes that "Under existing regulations, the best conditions for productive efficiency in weaving in humid sheds of the type under investigation seem to be obtained with a dry-bulb temperature of 70–75°F., and a relative humidity of 80–85 per cent." Wyatt's conclusions are supported to some extent by Maloney's investigations on output in India (4), which show that, while the best results are obtained during the monsoon for several reasons, the highest efficiency figure in one shed was 109.2 with a temperature of 84°F. and a humidity of 76 per cent., or with a temperature of 86°F. and a humidity of 74 per cent.; and the highest in another shed was obtained with 87°F. and a humidity of 71 per cent., or with 90°F. and a humidity of 67 per cent. It must be noted, however, that both sets of results apply only to sheds of particular type producing a particular cloth from a particular class of yarn treated in a particular way, and if all or any of these factors are varied the results must be different. What they do show somewhat definitely is that a raised temperature with lowered humidity and a lowered temperature with raised humidity have, within limits, an equivalent value.

What I wish to emphasize is that a manufacturer producing a particular quality of cloth chooses the yarn accordingly, and mixes the size; he then controls the shed humidity to what he considers the best advantage and, unfortunately, a bad warp is often one of the considerations. His greatest

task is to keep the percentage of humidity required at an even level, whatever the temperature; the more the temperature rises, the more moisture he must put into the atmosphere. For this purpose he uses both steam and vaporized water, either separately or in conjunction, and many most ingenious appliances are now available. He is still quite fond of steam, as it is very quick at rectifying a fall in humidity from such adverse atmospheric conditions as are brought about by a dry wind or a rise in temperature, and it is very efficacious in rendering shed conditions efficient on a cold morning. The use of steam is now prohibited, however, if the temperature is below 50°F., so that closed steam heating pipes must be utilized or warm air introduced until this temperature is reached. In view of the considerable divergence of opinion among manufacturers on what constitutes good weaving conditions, it would appear to be the proper course, from the standpoint of weaving efficiency, to establish an experimental shed and to make an exhaustive series of tests, with a view to ascertaining the most suitable temperatures and humidities for warps of different tensile strengths and with varying percentages of size.

Human Aspect

During the past fifteen years, many investigations have been made and a great deal has been written on the influence exercised by atmospheric conditions on bodily function and well-being. Though much good work had been done previously, it may be said that the campaign of enlightenment on the real significance of certain well-known physiologic reactions to equally well-known physical factors received its main stimulus when Prof. Leonard Hill, at the Dundee Meeting of the British Association, in 1912, disillusioned the public health world respecting the hitherto universally accepted chemical theory of ventilation and made it clear that the true reason for systematically changing the air of a room was to secure the maintenance of body temperature equilibrium by moving away the superfluous heat. In the spring of 1913 I had the privilege of hearing Professor Langlois describe his experiments, and, later in that year, of hearing Professor Hill explain his "revolutionary" views at a meeting in Manchester. During the time that has since elapsed, Hill, Chapman, Vernon, Langlois, Yaglou, Wyatt, and many others have done much to place our knowledge of the subject on a sound footing, and I recommend a perusal of their writings. In my own dealing with this phase of the question from its physiologic and physical aspects, it will be my aim to provide just the amount of information necessary to enable those interested to obtain a reasonable understanding of their bearing on the more purely technical problems to follow.

Physiologic and Physical Considerations.—We know that body heat is generated intrinsically by metabolism of the tissues and of ingested food, and that the chief centers of production are the muscles and the abdominal viscera. The functioning is at its lowest ebb during periods of complete rest, as during sleep, and this phase has received from Hill (9) the designation of "minimal metabolism." From this point the production of further heat is

a matter of increased expenditure of functional energy, muscular or otherwise. The heat so produced is dissipated through the skin and the lungs by transferring the hot blood from the active parts to these extensive cooling surfaces. The vasomotor mechanism adjusts this dissemination to the needs of the moment, and the regulation is so delicate that, whatever the call under normal conditions, the body temperature is maintained at 98.4°F. This equilibrium between heat production and heat loss is maintained under varying conditions of external temperature as well as of internal heat production, and the efficiency is such that a change from arctic to tropical climate does not create a difference of body temperature exceeding 1°C., and ordinary laborious work can be carried out without any alteration at all.

This regulating mechanism is tuned to react to certain external factors as well as to internal stimulus. Atmospheric qualities play a definite part in this maintenance of a constant body temperature. In a cold and temperate atmosphere, heat is transferred from the surface of the body to the surrounding air by radiation and convection, and from the lungs by convection and diffusion of vaporized moisture. Increased effort or a rise in external temperature increases respiration and the amount of blood supply to the skin, and if the methods mentioned prove insufficient to balance further heat production, the sweat glands are brought into function and heat is lost by vaporization of moisture immediately it is secreted (insensible perspiration) or by the slower process of evaporation of condensed sweat (sensible perspiration). When the external temperature reaches body temperature, radiation ceases, and convection can carry on only if the surrounding air is moving. When the external temperature exceeds that of the body, convection is reversed and the tendency is for heat to pass to the body; owing to the sufficiency of evaporation, however, this is ordinarily nonoperative and equilibrium is therefore not interfered with. If, however, with a high dry bulb temperature there is a considerable amount of moisture in the atmosphere, as shown by the fact that the wet bulb thermometer registers a temperature approaching that of the body, the regulating mechanism is apt to break down and heat stroke may supervene. This is not a necessary sequence, for even if wet bulb and body temperatures are equal, sweating can continue, and the body, being febrile, will again create a margin between the two and thus keep evaporation going. The efficiency of evaporation is clearly dependent on the actual amount of moisture contained in the atmosphere and not on the percentage or relative humidity; the human requirement thus differs materially in this respect from the manufacturing requirement. With complete atmospheric saturation at a temperature lower than that of the body, evaporation still proceeds owing to the fact that the transference of heat from the body reproduces the capacity for absorption of moisture. It is only by saturated air at actual body temperature for the time being that evaporation can be held up. Haldane (10), experimenting with men stripped to the waist, found that

the limit of wet bulb temperature which could be endured in still air was 88°F. when resting and 78° when ascending steps. Vernon (11) agrees with Haldane, but in addition points out the influence of acclimatization in increasing the limit of endurance. At the beginning of his experiments, Vernon states that at a wet bulb temperature of 76° to 77° his rectal temperature rose to 101.4° and he felt faint; after experimenting for two months he was able to bear a wet bulb temperature of 95.2° for a longer period with no faintness and only moderate dyspnea, the rectal temperature being at the same level as before.

As has already been mentioned, air movement counteracts both the ill effects of rising atmospheric temperature on convection and the bad influence of humidity on evaporation. With regard to the influence on dry bulb temperatures, some prewar experiments by Langlois showed that at 77°F. an air velocity of 400 feet per minute reduced the loss of moisture to one-half of the amount lost in still air at 75°F., convection coming into play in substitution. The effect in a humid atmosphere of the same air velocity was shown by this observer to increase the loss of moisture from 527 gm. to 1,340 gm. at 77°F., wet bulb temperature, and from 450 gm. to 930 gm. at 84.2°F., wet bulb. Haldane found that with air moving at 175 feet per minute his limit of endurable wet bulb temperature could be raised to 93°F. when he remained stationary, and to 85°F. when he was ascending steps. Obviously then, the more effectively the layers of heated or humidified air are removed from the neighborhood of the body and are replaced by fresh supplies of cooler and drier air, the greater becomes the efficiency of both convection and evaporation, either separately or in combination. Conversely, if the air is stagnant, that portion in contact with the body may become saturated at body temperature, irrespective of the general humidity; this occurs particularly in the clothed body through heating and saturation of the air between the skin and the clothes and in the clothing itself. Under such conditions high wet bulb temperature effects are necessarily experienced.

Kata-Thermometer.—At an early period in his investigations Professor Hill recognized the importance of being able to obtain some definite indication of the extent to which the external atmosphere could carry out its function of removing the excessive heat generated by the living body. He therefore sought a means of measuring atmospheric cooling power and produced his now well-known modification of a spirit thermometer (9). The stem is marked at 100°F. and at 95°F.; when the bulb is heated to raise the column above the top mark, the rate of cooling is shown by the number of seconds required for the column to drop through the 5°. For greater accuracy the equivalent of this fall in actual heat units lost is calculated and stated in terms of millicalories per square centimeter of surface per second. The heat lost per square centimeter of bulb surface during this particular drop is worked out for each thermometer, and when this figure, known as the factor and engraved on the instrument, is divided by the number of seconds noted, the cooling power of the atmosphere in

units per second at the time of the observation is disclosed.

The theory of the kata-thermometer appears to be that the rate and the amount of heat loss from a given surface of a body at the same temperature as the human body should indicate fairly accurately the loss from an equivalent surface of the latter when exposed to the same atmospheric conditions. When the uncovered instrument is used, the resulting figure shows the amount of heat dealt with by radiation and convection, and is known as the dry kata cooling power; when the bulb is covered with a wet silk stall, the calculated figure indicates, in addition, the heat lost by evaporation and is known as the wet kata cooling power. The difference between the two results, when both methods are being used, indicates the cooling power exercised by evaporation only. There is not much use in trying to get dry kata readings when the dry bulb temperature reaches 90°F., unless there exists a very pronounced air movement, for at 95°F. the cooling power is zero; the value of these readings at ordinary temperatures is, however, undoubted, very largely owing to the fact that from them can be ascertained the velocity of air currents. It is necessary simply to note the dry bulb temperature at the time of observation, to divide the dry kata figure by the difference between this and 97.7, and to look up the velocity indicated opposite the resulting figure in a table already worked out, which is supplied by the makers of the instrument. With high temperatures, wet kata readings must be relied upon for ascertaining the cooling power, but there are many instances where it is advisable to take both sets of readings.

After providing a method of ascertaining cooling power, it was quite a natural follow-up procedure to ascertain what dry and wet kata figures under fixed conditions of heat production corresponded to atmospheric conditions yielding the greatest feeling of comfort to the individual. Hill has come to the conclusion, after much consideration and many observations, that a dry cooling power of 6 and a wet cooling power of 18 may be taken as indicating most suitable conditions when light work only is being carried on, and these figures have been widely adopted as kata standards. I do not insist that as standards they represent finality and that they will not be subjected, as the result of larger and more varied experiences, to some modification, but I do recognize their present utility as standards and the consequent power which they give for comparison of results; if the upsetting factors are known, allowances can be made for them when gauging the satisfactory or unsatisfactory qualities of atmospheric conditions. For instance, the clothing factor is known to be exceedingly variable both as to amount, quality, and conducting power. Hill (12, p. 239) found that at 64.9° atmospheric temperature with a mild breeze blowing a naked kata cooled two and one-half times faster than it did in still air at 61.3°, but that it cooled only 85 per cent. faster when the kata was covered with a silk stall and only 46 per cent. faster when it was covered with a woolen stall. Vernon's more recent experiments (13, p. 67) show that an air current at 100 feet per minute, as

contrasted with still air, produces an extra cooling power corresponding to a lowering of air temperature by 2° to 4°, while in a warmly clad body it corresponded to a lowering of only 1°. That there is, on occasion, a lack of correspondence between kata readings and comfort has been pointed out by Vernon (11, p. 141) in citing various combinations of temperature and air velocity yielding the same cooling power of 7—*viz.*, 51°F. with still air, 64.5° with an air velocity of 40 feet, and 87.5° with an air velocity of 1,074 feet. He states that, while the medium condition would be quite comfortable, 51° would be too cold, and 87.5° too hot. These ascertained facts do not, in my opinion, destroy the value of the kata, but rather point to the necessity of taking into account all factors when making observations. Taken at its true valuation, it certainly provides a link in the chain which is proving of immense service.

The kata-thermometer has not attained its widely accepted position without the appearance of a rival, for in the United States there has been devised a very clever system which aims at assessing atmospheric conditions by what is known as the "effective temperature." The scheme is founded on the principle that a definite atmospheric quality can be attained by varying combinations of the regulating factors of dry bulb temperature, wet bulb temperature, and air movement (14). The atmospheric qualities corresponding to a considerable series of combinations have been assessed by experiment and their equivalent single constants as ascertained are the effective temperatures. Two charts have been devised to enable the observer to ascertain the effective temperature for any particular combination of the three factors (1) when the individual is stripped to the waist (basic scale), and (2) when the individual is lightly clothed (normal scale). Each scale is a series of lines at an angle of 45°, representing air velocities, which are crossed by another series marking degrees of effective temperature, and these are flanked by vertical thermometer scales, the left representing dry bulb and the right representing wet bulb. The point where a line drawn from the observed wet bulb temperature to the known dry bulb temperature meets a crossing of the known velocity line and an effective temperature line indicates the effective temperature in the case. The effective temperature lines from 63° to 71° represent the "comfort zone." If the effective temperature equivalent to the known combination in a particular instance is regarded as unsatisfactory, another combination, or another series of combinations, can be devised which will meet the circumstances of the case and will bring the point of crossing within the comfort zone.

I can appreciate the suitability of this method to American systems of mechanical ventilation where the air current can be measured by anemometer, but I am not equally convinced that the system can take the place of the kata-thermometer under conditions which require dealing with in other parts of the world. The kata possesses the quality of being able to indicate the rate of air movement in any part of a given space, and that this is a real advantage in gauging comfortable working conditions I know

from personal experience. Possibly some combination of the two systems would prove useful in suitable cases.

Mechanical and Human Interests in Association

Having dealt with the influence exercised by temperature and humidity on both the mechanical element and the human element, I have now to show to what extent efforts have been made to reconcile apparently conflicting interests, the faults still needing rectification, and the lines on which further accommodating measures must be devised in order to provide working conditions which will prove mutually satisfactory.

Spinning.—The 1902 Report of the Departmental Committee on Ventilation of Factories and Workshops (6) contains a long table of results of observations in spinning mills, and these show quite conclusively how much the manufacturing conditions and how little the human needs were considered only a few years ago. The small number of mills that were reasonably ventilated and the fewer mills that had combined ventilating and humidity systems had even then reasonable temperatures and humidities, but the large number, nearly all spinning fine counts, which were not ventilated at all had without doubt unnecessarily high temperatures and humidities. Hermetically sealed windows, fireproof floors and ceilings, and painted walls prevented even diffusion of air between inside and outside; indeed, it is stated, in one case, that it would take fourteen hours to effect one change of air, and, in others, that the carbon dioxide from gas jets became so excessive (up to 56.6 per 10,000 cubic feet) that most of it was there when work was started the following morning. Another mill had 1,056 square feet of glass to 2,702 square feet of wall space, and got very hot from the sun's rays. These conditions occurred in rooms provided with up to 10,000 cubic feet of space for each person, and an average temperature in January of 90°F. Conditions have altered materially in twenty-five years, and fine spinning mills, which formerly offended so badly, are now excellently provided with mechanical methods for filtering the air and for regulating the supply, temperature, and humidity. To the improved conditions in this direction must be attributed, to a large extent, the improved general health of cotton operatives referred to in a previous section.

It is quite obvious that where spinning rooms are provided with up-to-date air conditioning apparatus, they must also have both dry and wet bulb thermometers put up in the rooms themselves, in order to check, periodically and at any time, the hygrometric state of the atmosphere and so to provide indications for any necessary adjustments; and this is the case. Such factories have therefore the necessary data for investigation, and, as it is the custom to take regular readings twice each day and to enter the results on cards provided for the purpose, there are plenty of systematic records available for inspection and study. It has been my privilege to analyze a ten years' complete record taken at a group of four mills, and the charts given show results compiled from typical rooms in each mill.

The records which I have chosen

are for yearly periods, except those shown in Figure 5 which are for ten months only, and show the monthly

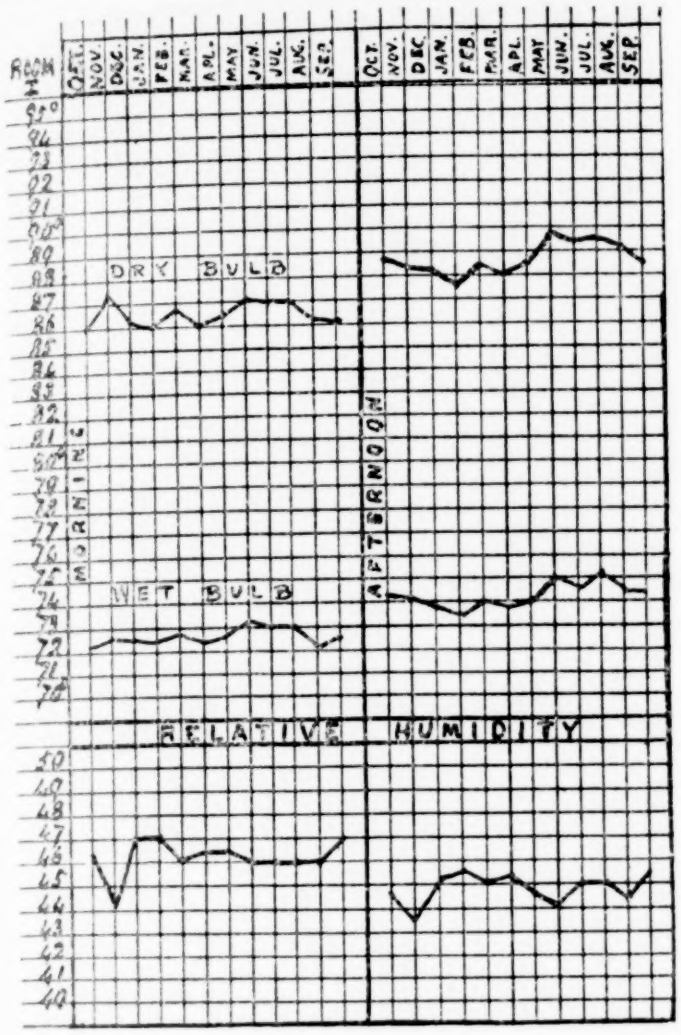

FIG. 1.—Monthly mean figure of morning and afternoon dry and wet bulb temperatures and relative humidities in spinning room No. I.

mean figure of the morning and afternoon wet and dry bulb temperatures and relative humidities. Figure 6 gives the outside mean maximum dry bulb temperatures in the shade for each month during the same period. The time covered is from the beginning of October, 1924, to the end of September, 1925, and I have encroached on two successive years in order to indicate more clearly the difference, such as it is, between winter and summer figures.

The curves as a whole show how closely the temperature and humidity conditions are confined within the limits I have previously given. The afternoon temperatures are higher than the morning ones, but the humidity percentages are kept at a fairly even level throughout both the day and the year. The room variations are due to some extent to difference in counts, but there are additional reasons which will be explained later. The curves in Figures 1 and 4 are really remarkable, and show how well atmospheric conditions can be

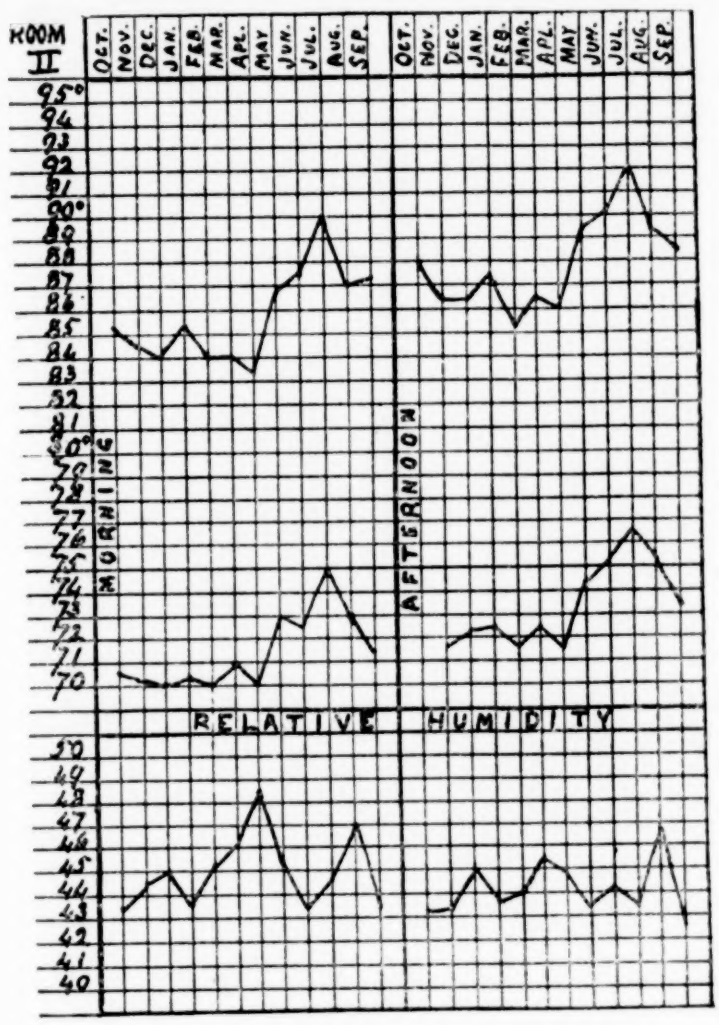

FIG. 2.—Monthly mean figure of morning and afternoon dry and wet bulb temperatures and relative humidities in spinning room No. II.

controlled. The daily variation is between 1° and 2° only, and the monthly variation is kept well within the same range in spite of seasonal changes. The other three spinning rooms, though showing equable results for the greater part of the year, appear to have been readily influenced by outside temperature during May,

June, July, and August—two producing variations of 6°, and the other a variation of 4°. On seeking the cause

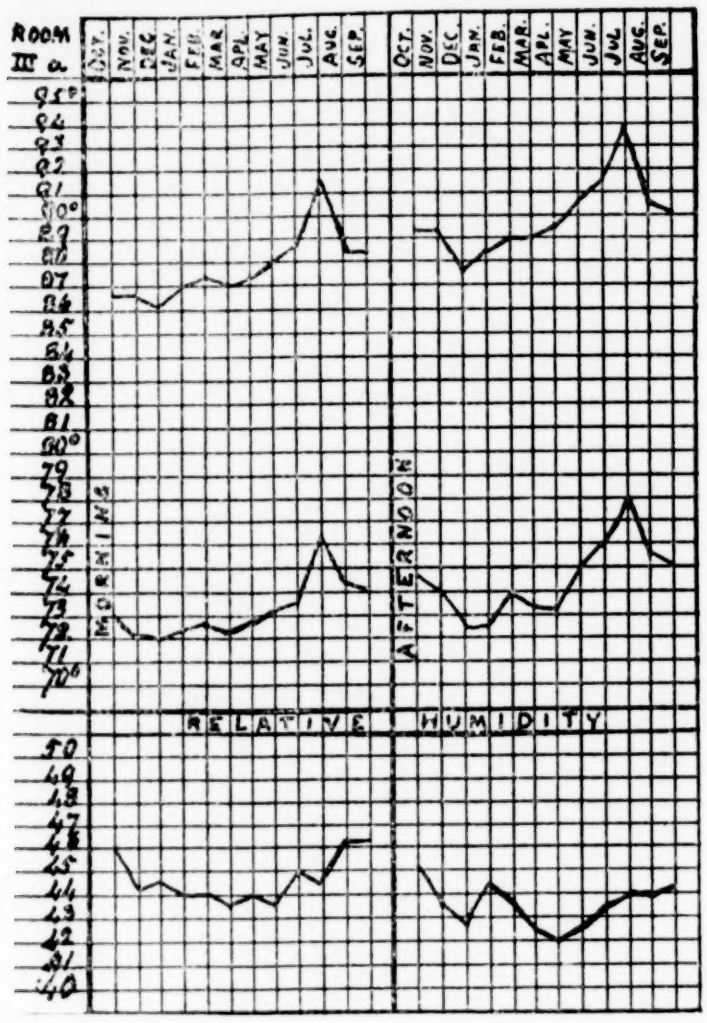

FIG. 3.—Monthly mean figure of morning and afternoon dry and wet bulb temperatures and relative humidities in spinning room No. IIIa.

of these summer variations, it was ascertained that in all the rooms concerned the humidifying plant can be regulated from inside the room, and that in the rooms with even temperatures this cannot be done. Spinners will try to regulate the water sprays in hot weather, if they have the opportunity afforded them, and each spinner in the room has different views on the subject, though all of them appear to be fond of a high temperature. The humidifiers are kept under regulation scientifically in all the rooms by the hygrometer attendant, but where the periodic adjustments are interfered with, the usual even results are easily destroyed. The remedy for these irregular attentions to the ventilation is to limit them to the overlooker when the apparatus is not installed in a separate compartment capable of being locked up.

The humidity question requires more consideration than would appear to be the case at first sight. It is true that, for the sake of the cotton, the

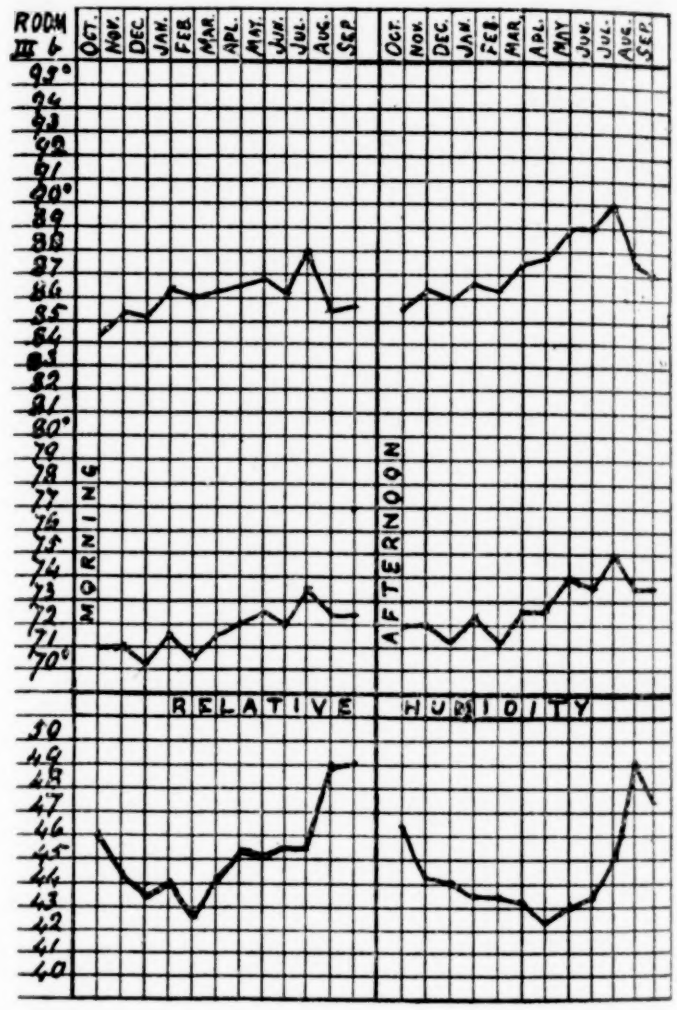

FIG. 4.—Monthly mean figure of morning and afternoon dry and wet bulb temperatures and relative humidities in spinning room No. IIIb.

percentage is kept low, but the facts must not be overlooked that the maintenance of the desired proportion means the provision of a considerable amount of moisture over and above that of the outside air at the high temperature required for successful spinning, and that it is the quantity

and not the percentage which concerns the operative. The charts show how exactly the wet bulb temperature rises and falls with the dry bulb temperature and that, in well-conducted mills, it is always above 70° and frequently above 75° or even more than that. It is, as I shall have to point out later, the exceeding of these limits which constitutes the chief cause for complaint against wet

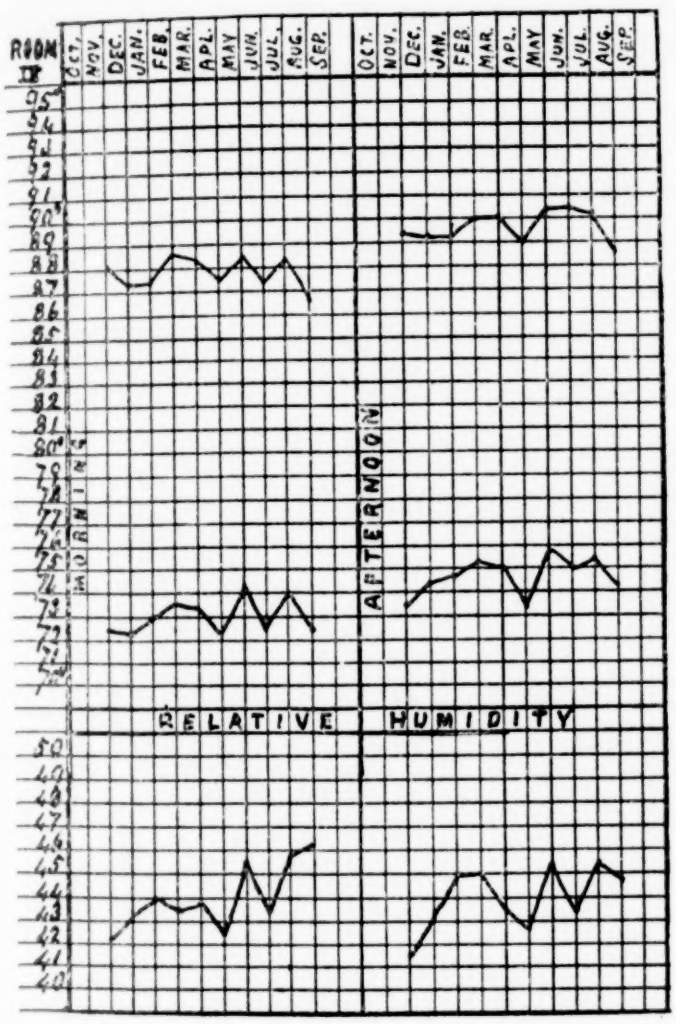

FIG. 5.—Monthly mean figure of morning and afternoon dry and wet bulb temperatures and relative humidities in spinning room No. IV.

weaving sheds. The nearer the wet bulb temperature approaches that of the body, the more watery vapor the air contains, and consequently the less accommodation it possesses for perspiration exuding from the worker; thus the strain on the worker's heat regulation is increased. Humidity in spinning rooms is therefore an important factor and merits serious attention.

In considering air movement, it

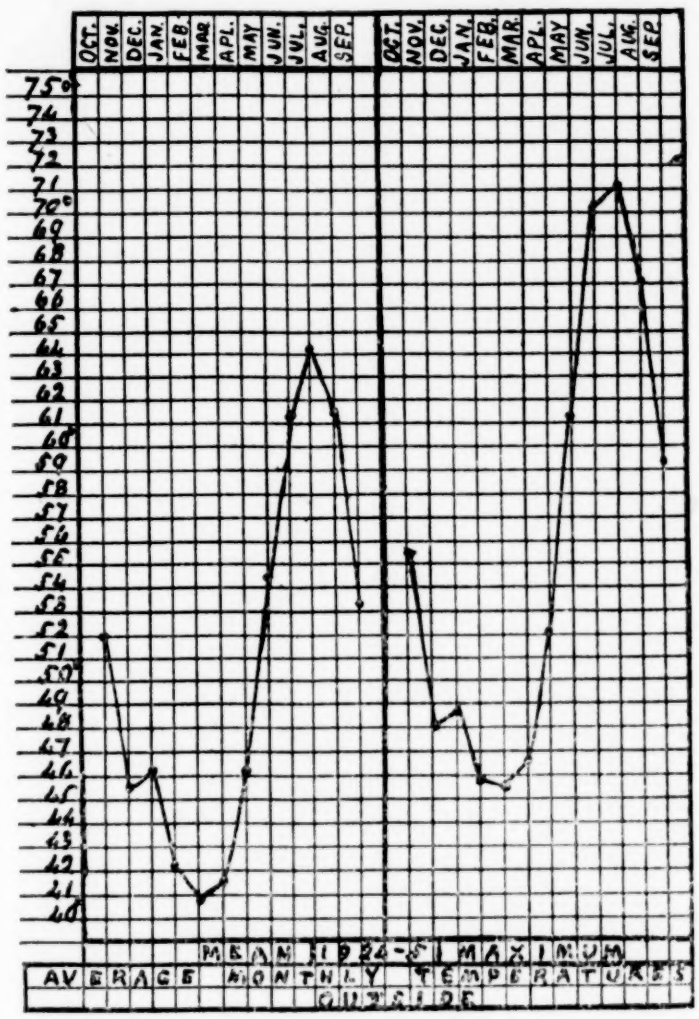

FIG. 6.—Average monthly outside dry bulb temperature in shade.

must be understood in the first place that this receives little encouragement in spinning rooms where fine counts are being dealt with. The conditioned air from outside is driven along one or more tubes running the length of a room, and emerges at regular intervals through a series of graduated outlets; the air exits are the doorways, of which there are generally two to a room. To insure that no air enters by unauthorized routes a slight plenum is aimed at, and when this is exceeded the swing doors are pushed outward; the escape of air relieves the pressure and the doors coming together again are ready for the next puff. Under such conditions there is no

appreciable air movement a few feet away from the duct openings. This deficiency in sensible movement at high temperature is reflected in some typical examples of wet kata-thermometer readings taken in August, 1926, which also show that diminution in cooling power follows elevation of wet bulb temperature when there is no undue interference by air current.

Dry Bulb Temperature	*Wet Bulb Temperature*	*Wet Kata Cooling power*
°F.	°F.	
94	78	9.0
89	76	10.0
88	76	10.0
89	74	10.3

Standing 4 feet from a doorway with one of the swing doors two-thirds open a wet kata cooling power of 10 advanced to 18.8 and the dry kata showed an air velocity of 73 feet per minute. Maloney (4) took a large number of wet kata readings in Indian spinning mills, and the monthly means of the three readings per day show very definitely that the cooling power decreases at each reading in proportion as the wet bulb temperature rises.

The next consideration is the clothing of spinning room operatives. In mule spinning rooms, whatever the counts spun, men and boys are employed, though in Manchester fine spinning factories both sexes are engaged as piecers and scavengers; in ring spinning rooms, females are exclusively employed. The men are quite suitably attired for the work in cotton shirt or singlet and cotton trousers or blue overalls, but the females are not always clothed so suitably. They may simply take off the outdoor dress and don an overall; whatever is under the dress, whether little or much, in coming to the mill remains under the overall, but where there is welfare in vogue the supervisors have, in my experience, made giant strides in establishing a more rational dress. Both sexes have bare legs and feet.

Having previously explained the manner in which high temperature and humidity affect the individual, I must now show the extent to which the spinner is brought within the scope of the principles enunciated. He has to put up with both these atmospheric qualities and, in fine spinning mills, with a low air velocity, all the year round. For a short period in summer, more particularly in coarse spinning mills, these conditions are intensified. To this atmospheric state the spinner is, however, exceedingly well acclimatized, and unless the temperature is excessive or unless he indulges in extraordinary muscular effort he easily attains and keeps his own temperature equilibrium. It is a feature of this ready adaptability that the body quickly adjusts its blood supply to the atmospheric needs and that the adjustment continues throughout the working day. This means that larger quantities of blood are required for parts which under average circumstances want very little, and that certain parts, such as the brain and the digestive organs, which ordinarily need a good supply, have to get along with less. The existing quantity has to go further and to do more, and as a consequence an extra strain is thrown on the heart for a considerable period of the day. This in turn produces a tendency to fatigue after moderate

exertion; metabolism is lowered with lower blood pressure and so assists accommodation somewhat, but this is not good for the general nutrition of the body. This explains anemia and digestive disturbances and, to some extent, the prevalence of rheumatic affections.

In the colder months of the year the change to a much lower temperature on leaving work, particularly to the overclothed, brings about a sensation of cold; the respiratory mucous membrane is chilled, its blood vessels are constricted, and the activity of the ciliary epithelium and the leukocytes is interfered with, which explains the special susceptibility to colds, influenza, bronchitis, and tonsillitis. On the other hand, Dr. E. M. Brockbank (15) of Manchester has noted that cotton operatives under 50 years of age enjoy a somewhat remarkable freedom from the ill effects of high blood pressure. He found high systolic pressure in fifty-nine out of 197 women and in forty-three out of 136 men claiming inability to work from various causes, 80 per cent. of those examined being over 50 years of age and 60 per cent. being over 60 years of age. He thinks that this immunity may be due to the regular removal of waste products of metabolism by perspiration, a process materially assisted by their custom of drinking 2 or 3 pints of tea or water a day. He also mentions that cotton operatives do not eat an unusual amount of flesh foods and are a very temperate body of workers. It is thus interesting to learn that working in spinning rooms where the temperature is high has its advantages as well as its disadvantages to the human economy.

The final point for consideration has relation to the methods which should be adopted to prevent the ill effects that I have described. In the first place, the temperature necessary for the particular counts being spun should not be exceeded, and in no case should it be allowed to rise above 90°. It is generally recognized that sweating should be avoided, and my inquiries show that this rarely occurs at the accepted temperatures but is common when the thermometer registers over 90° or when the spinner has to do a strenuous job, such as replacing a draw band. In fine spinning rooms, which require the higher range, this restriction is particularly important because of the slow air movement and the relatively high wet bulb temperature. That the temperature can be satisfactorily regulated in this type of factory is amply demonstrated by the charts which I have provided. As I have already explained, mills spinning the lower counts have a lower range and are satisfied with outside air unaltered for reasons given. In summer, however, the inside atmosphere is more affected by extreme heat and solar radiation than is the case with the more exactly regulated fine spinning rooms, and the temperature may rise to 100°. This necessitates artificial humidity, and where humidifiers are installed they are started when breakages become too frequent. The remedy is increased air movement, and this type of mill should be more conveniently supplied with propulsion fans and ducts to assist the windows than is the case at present; furthermore, it would be a distinct advantage both for cooling purposes and for humidification

to have water vaporizers acting in conjunction. Such an installation would prove of particular value when dry winds are prevalent and necessitate the closing of windows. I know that complete air conditioning apparatus is regarded as too expensive for mills spinning low-priced yarns, but my proposition is a compromise and should not involve anything like the cost of these systems. Ring spinning rooms also are unduly heated in the summer months, but the process can very easily allow provision for increased ventilation by either propulsion or extraction fans and ducts. Humidity is not so big an item here as in mule spinning, owing to the short length of yarn between the rollers and the spindle. I further think that wet and dry bulb thermometers should be put up in all spinning rooms to indicate when interference with temperature, humidity, or air movement is needed, and that rule of thumb methods should be severely discouraged.

With regard to clothing, I have no complaints to make about that adopted by males but would suggest that every effort should be made to instruct females on the most suitable attire for spinning mills. With the uniform high temperature throughout the year in fine spinning rooms, bloomers, singlet, or blouse, and overall are quite enough to wear; this applies also to the other varieties of spinning during the summer months. A skirt and blouse may be added during the colder months in the rooms with lower temperature. It is unfortunate that spinning mills are universally without dressing rooms; this means that when females are properly attired they have to dress for the mill at home, putting on an extra skirt and jumper to take off in the spinning room.

Though I have not systematically taken the temperature of workers in the spinning rooms, I have taken it in a considerable number of cases in the clinic, and have found no elevation which could be attributed to the atmospheric conditions except in the cases of a number of young persons during the first few weeks of employment. I believe that acclimatization is sufficient to account for this, and that the only likelihood of supernormal body temperature would arise when the room temperature exceeds 90°F.

Preliminary and Subsidiary Processes.—As I have previously pointed out, in none of these processes is artificial humidity really required in Lancashire, nor is the temperature excessive in the summer except in doubling rooms. In speed frame rooms the temperature may be over 80°, but this is neutralized by the high air velocity produced by the rapidly revolving flyers on the spindles. As moderate air currents are not conducive to breakages or bad work in these departments, efficient ventilation by extraction fans either with or without ducts can be safely utilized, or, if the air requires filtration for any process, propulsion fans and ducts can be substituted. Though I know of instances where card rooms and speed frame rooms are supplied with a full conditioning plant, I am not satisfied that this is necessary. Though some gassing rooms are still objectionably hot and stuffy, those of the modern type are so efficiently provided with mechanical ventilation that

the workers no longer suffer discomfort. There is a considerable movement of air in blowing rooms owing to the draw of the fans in the opener and scutcher machines. Table 5 shows the dry kata cooling power and the air velocity in feet per minute taken in different departments at a typical, well-conducted fine spinning mill during October, 1926.

TABLE 5.—DRY KATA COOLING POWER AND AIR VELOCITY IN WELL-CONDUCTED FINE SPINNING MILL, OCTOBER, 1926

DEPARTMENT	TEMPERATURE	DRY KATA COOLING POWER	AIR VELOCITY	VENTILATION
	°F.		*ft. per min.*	
Card room:	75			Windows; extraction fans (not working).
Between cards		4.2	22	
Between drawing frames and combers		4.3	25	
Between roving frames		6.3	109	
Blowing room		6.0	93	Natural; also intake of openers and scutchers.
Doubling rooms:				
No. 1	78	7.2	238	Propulsion and air filtration.
No. 2	78	4.6	59	
No. 3	60	5.0	116	
Clearer winding room	71	6.0	47	Windows.
Hank winding room	69	6.0	38	Windows.
Gassing room	72	7.6	132	Local ventilation of gas jets.
Cop winding room	64	6.6	28	Propulsion and air filtration.
Jack room	70	5.2	24	Natural.

Weaving.—I have indicated earlier that dry sheds are not difficult to deal with. Like all other cotton factories there is no overcrowding, nearly all sheds providing over 1,000 cubic feet of air space to each individual; but in spite of this fact the 1902 Report of the Departmental Committee on Ventilation of Factories and Workshops (6) showed that very little attention was being given to air movement, that it was quite common to find ventilators blocked up, fans out of action, skylights closed, and up to 0.4 per cent. of carbon dioxide in the atmosphere. The establishment by the 1911 Regulations of a carbon dioxide limit of 11 parts per 10,000 above the outside air content has, however, compelled better observance of requirements in this direction. Cooling power now appears to be fairly reasonable, judging from some figures published by Wyatt (16) which show a mean dry kata figure of 5, a wet kata figure of 17.3, and an air velocity of 28 feet per minute as a result of twenty-four observations made during the summer of 1920.

Wet weaving sheds provide a much more difficult problem, a problem, by the way, which would not exist if manufacturers would so compound their warp size that artificial humidity would not be required. Unfortunately, the cost of softeners and deliquescents in sufficient quantities to be effective is held to be prohibitive, and as moisture is effective as a softener, and relatively cheap to produce, it scarcely seems likely that it will be superseded. Excessive humidity in weaving sheds has brought about a considerable amount of legislation and has produced several sets of Regulations; its effects on the worker have been the subject of much investigation, and a great deal has been published on this phase of the question. There is, therefore, so much information already available that I may justly consider myself excused from giving more than a summary of the influence exercised on the individual by unsatisfactory atmospheric conditions in these factories.

Though a report to the Privy Council, issued in 1861, noted the undue prevalence of pulmonary disease in Blackburn and, following a representation from a Trade Union Congress, a report was made to the secretary of state by Dr. Bridges and Mr. Osborne, in 1883, on the "Effects of Heavy Sizing in Cotton Weaving upon the Health of the Operatives Employed," the first real move toward improvement undoubtedly got its start as a result of a declaration (1887) by Dr. Stephenson, a former medical officer of health of Blackburn (2) to the effect that the high death rate of the town was due to a wholesale slaughtering of the inhabitants by effusing steam into the factories and polluting the atmosphere with dense black smoke from the chimneys. As a direct consequence of this particularly strong indictment, the Blackburn Corporation appointed a committee, which subsequently reported that ventilation was inefficient and that heavy steaming was injurious, but that light steaming combined with proper ventilation was not injurious. This agitation at Blackburn produced the Cotton Cloth Factories Act of 1889. Sir Henry Roscoe's committee was appointed in 1896, owing to further strong protests against steaming from the Weavers' Association, and was followed by the Act of 1897; this Act being subsequently incorporated with the Factory Act of 1901. More protests from the weavers, in 1906, resulted in the formation of another departmental committee with wider references; and this was followed in due course by the Act and Regulations of 1911, which are still in operation.

These different Acts brought about improvement by stages, and to my mind each stage has proved its own value. The first established the wisdom of taking hygrometer records, of limiting the humidity, and of making ventilation compulsory; the second showed the importance of keeping down temperature and the need for standardizing ventilation; the third emphasized the significance of wet bulb temperature and the necessity for its limitation as well as for the fixing of a definite relationship to dry bulb temperature, the need for prohibiting steam at a fixed wet bulb temperature and for fixing a standard lagging for steam pipes, and the decrease in importance of a high car-

bon dioxide standard (7). I regard all these factors as good bricks in the protective wall round the worker, but I have formed a strong opinion that the one to produce the most far-reaching effects is that which secured a compulsory standard of ventilation, and the fact that this was established before the physical theory superseded the old chemical theory of ventilation does not affect my point. The change in theory does not negative the value of the carbon dioxide figure as an indicator of the amount of air being provided, and 9 parts per 10,000 stood for free air movement. Now free ventilation and unscientific steaming are plainly incompatible, and this obvious fact brought into operation the ventilating engineer and started the production of mechanical devices for providing the requisite amount of air, keeping down the temperature and, at the same time, maintaining the humidity at the right level. Twenty years ago Dr. A. Greenwood (2) was able to say that a modified plenum system was the one most utilized in Blackburn, and there have been remarkable improvements in humidifying plants since then. Through the introduction of mechanical methods of ventilation and humidification into weaving sheds as a direct result of fixing a carbon dioxide standard, the cotton trade is in a much more favorable position to obey the dictates of the kata-thermometer or the effective temperature chart than it could possibly have been otherwise. Quite a number of appliances follow up-to-date precepts and can deal with air either from inside or from outside the shed, as desired. As a statutory standard, the carbon dioxide figure should not be scrapped until, shall we say, a more suitable kata standard or standards can be devised in substitution.

I know that one has to be cautious in changing standards in view of past pronouncements of expert committees. We were first told that the weaving problem was a matter of ventilation, next that it was a matter of wet bulb temperature, and now the kata-thermometer indicates once more that ventilation or air movement is what matters and that it is really questionable whether the 1898 standard should have been cut down.

I also regard the temperature factor as one of the most important, for it is invariably an undue elevation of this which brings about adverse conditions affecting the individual. Indeed, high wet bulb temperature, which is so particularly unfavorable for the worker, would never be in evidence if dry bulb temperature were kept within reasonable limits. The physiologic effects of high temperature and humidity have already been dealt with in a general way, but a number of special investigations which have been made in the cotton weaving industry should not be overlooked.

Legge (7) found that weavers are subject to a rise in mouth temperature when the wet bulb temperature exceeds 75°. Pembrey and Collis (7), experimenting on themselves and on a number of weavers, found elevation of temperature, quickened pulse, quickened respiration, and lowered blood pressure when the wet bulb temperature was much over 70°. These latter observers, as well as Legge, noticed that in women the mouth temperature was consistently higher than in men, and this is ascribed

to the greater amount of clothing worn. On the other hand, as the result of over 16,000 observations on body temperature in Indian mills, Maloney (4) is of the opinion that it is not possible to say that this begins to be adversely affected at a given wet bulb temperature. In India, at all seasons of the year the temperature of mill operatives rises somewhat during the day, but weavers do not experience a greater rise than do those working in other departments under better conditions. Even with wet bulb temperatures from 85° to 90° the body temperature rarely rises to 99.5°. Maloney thinks that this difference may be due to the following facts: that basal metabolism is about one-half that of the European, that work slacks off and frequent visits are made outside during the hot weather, and that very scanty clothing is worn in Indian weaving sheds. Besides the tendency to diminished resistance to illness, due to the chronic strain on the circulation from excessive peripheral blood supply during the eight hours of each working day, there is a susceptibility to chills on leaving work. The humid air at mill temperature percolates shawls and coats hung up in the shed, as well as the clothes being worn, and these become damp or even wet from condensation at outside temperature, thus bringing about a too rapid conduction of heat from the body.

The general principles regulating the prevention of these ill effects aim at (1) producing reasonable temperature, (2) providing suitable clothing, (3) keeping outer clothing dry while in the mill, and (4) producing effective air movement.

The 1911 Regulations, though now approaching the out-of-date stage, as in the case of their predecessors, have done much to help preventive treatment. Temperature is dealt with by regulation of the length, diameter, and insulation of steam pipes used for humidification; by limitation of the size of uncovered jets to $4\frac{1}{2}$ inches and of steam pressure to 70 pounds; by fixing the minimum height of the shed, ordering the roof lights to face in a northerly direction and to be fixed at an angle of not more than 30° to the vertical; by separating the boilerhouse and engine room from the working room by a good alleyway and by keeping boiler flues at a distance; by whitewashing outside and inside of roof windows; and by forbidding the introduction of steam when the wet bulb temperature exceeds 75°F. Cloak rooms must be provided for changing and storing outer clothing in factories built after Feb. 2, 1898. Air change is provided for by the fixing of a minimum carbon dioxide standard. High wet bulb temperature is a sequel to high dry bulb temperature, as previously indicated, but in order to secure a reasonable relationship between the two a schedule is devised which indicates the nearest approach the wet bulb temperature may make to the existing dry bulb temperature. Up to 70° wet bulb there must be a margin of 2°, and between 70° and 75° wet bulb the difference between the two scales increases by steps from 2.5° to 5°. Clothing is apparently too much of a personal affair to be made subject to regulations, but what is really wanted in order to effect a general and hygienic practice in dress is a system of instruction, either

personal such as is undertaken by a welfare worker, or by a suitable leaflet. The main point is to regulate the

TABLE 6.—DRY AND WET BULB READINGS INSIDE AND OUTSIDE A WEAVING SHED (MILL LI) IN CENTRAL PROVINCES, INDIA[1]

MONTH	FIRST READING				THIRD READING			
	In Shed		Outside		In Shed		Outside	
	D. B.	W. B.	D. B.	W. B.	D. B.	W. B.	D. B.	W. B.
1919	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.
November	72.5	66.0	70.8	63.2	77.5	72.6	84.2	67.3
December	63.9	58.1	61.8	55.7	73.4	67.7	80.1	62.2
1920								
January	65.5	60.0	63.0	56.6	72.9	68.1	82.0	63.9
February	66.4	58.2	67.9	56.7	73.3	68.1	88.1	66.8
March	71.6	63.6	77.7	62.5	77.3	71.0	97.1	68.9
April	77.0	68.7	86.6	67.3	81.2	73.7	101.1	71.2
May	79.7	70.2	90.6	70.0	82.2	72.8	103.2	73.2
June	83.4	75.2	88.2	74.4	86.2	79.9	99.0	76.4
July	78.8	75.0	79.4	73.2	84.7	79.1	84.5	75.1
August	78.6	73.8	79.5	72.6	84.8	78.3	85.9	74.6
September	79.1	74.4	81.2	73.4	83.4	78.3	90.3	74.6
October	73.7	65.2	79.0	65.7	78.5	73.1	93.3	68.7
Annual average	74.2	67.4	77.1	65.9	79.6	73.6	90.7	70.2

[1] Abstracted from Tables 30 and 34 of Maloney's report (4).

clothing according to the temperature, and when this is high to have as much of the body surface as possible under the direct influence of the atmosphere. The prevention of high temperatures can be aided by building on a clay subsoil, by building against rising ground so that the soil is in contact with a fair proportion of the wall space, by building in a position sheltered from the sun, by constructing double roofs and flat roofs which can be covered with water, by installing water sprays on roofs, and by utilizing humidifiers fitted with water atomizers or sprays. Maloney (4) makes much of a shed in the Central Provinces which has large underground ducts, fitted with water sprays, which discharge saturated air at a lowered temperature in close proximity to the looms themselves; the result being that work is carried on during the hottest weather at a temperature lower than that outside (see Table 6).

Maloney's report to the Indian Government (4) was published in 1923, and in the same year Wyatt's report (16) on behalf of the Industrial Fatigue Research Board was also issued. Both these observers were able to utilize the kata-thermometer as a means of estimating the cooling power of the atmosphere in the sheds, and both were able to show that this quality is not so great or so constant as it ought to be. Both are agreed that the want of constancy is very largely due to variation in the amount

of steam used in different sheds. Wyatt shows that, in spite of Regulations presumedly well observed, weavers have still very commonly to work in stagnant air and to experience the attendant discomfort. The sheds selected for the observations were apparently reasonably provided with means for humidification and ventilation; some worked the two in combination and others worked them separately. The winter results showed that only one shed exceeded Hill's dry kata standard, the figure being 6.2, the others gradating from this to 4.3; none reached the wet kata standard of 18, the highest wet kata being 17.7 and the lowest 13.1. The dry bulb temperature ranged from 65.5°F. in the best shed to 74.3°F. in the worst. The results in general indicated that the cooling power became unsatisfactory when the shed temperature exceeded 70°, that conditions grew worse as the day progressed, and that a dry kata cooling power of 5 and a wet kata cooling power of 15 were sufficient to prevent sweating. A series of summer observations provided worse results. The dry bulb thermometer registered from 71.3° to 77.5°, the dry kata from 3.8 to 4.7, and the wet kata from 12 to 14.2. A succession of weekly averages at one mill showed that a diminution of 2 points dry and 4 points wet kata corresponded to an increase of 8° in temperature; a circumstance which quite supports my view that the first essential in bringing about reasonable conditions is to put an end to temperature irregularities.

If the temperature cannot be lowered, the only alternative way to get the proper cooling is by increasing air movement, but with the separate ventilation and humidifying arrangements in use at so many sheds this would mean lowering the relative humidity and a demand for more steam to regain the percentage. This alternative is more likely to prove successful where combined humidifying and ventilation systems are designed to deal with the air within the shed, though I think the most useful function of such combinations, if properly managed, is to keep the temperature low in the first instance.

Both Wyatt and Maloney have experimented with a variety of punkah attached to the heald roller as a means of providing local air currents, and have had very good results, the only objection, though an important one, being that the device would be apt to interfere with the weavers' examination of the warp. Paddles bolted on to shafting and electric fans have been tried, but they have not proved so effective as the heald roller device.

The reports of both Wyatt and Maloney clearly indicate that, apart from other requirements, there should be means available for securing better air movement. In my opinion much could be done in this direction by fixing separate kata cooling standards for wet weaving sheds, though I am not prepared to say that Hill's standard for sedentary work would quite meet the case; I believe rather that the figures should be varied according to temperature. Something in the nature of 6 dry kata and 16 wet kata for temperatures below 70° and 5 dry and 14 wet for temperatures above 70° might prove reasonable. Maloney suggests a minimum standard of 11 wet kata for Indian factories,

where temperatures mostly are too high for the dry kata to be used, but he has clearly shown that Indians can get along comfortably with a lower atmospheric cooling power than can operatives in England.

Lastly, I would impress the view that the varied combination of factors on which effective temperatures are based point a good lesson to the weaving industry. I have already shown that the same high percentage of efficiency in weaving can be obtained by different combinations of wet and dry bulb temperatures and would suggest that the aim of shed managers should be to use the particular combination most suitable for the weaver and to increase his comfort further by providing the right amount of air movement, which factor, *per se*, has no influence on temperature or humidity, but is of material assistance in providing the right kata figures.

(*To be continued*)

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A CLINICAL STUDY OF THE EFFECTS OF MINE GASES*

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THIS study was undertaken in order to obtain more accurate information regarding the clinical effects on man of abnormalities in the air of bituminous coal mines. The subject is complex and few accurate data are to be found in the literature.

The dangerous gases or mixtures of gases commonly found in coal mines are relatively few. They are carbon monoxide, carbon dioxide, methane, the oxides of nitrogen, hydrogen sulphide, and sulphur dioxide (1). Hydrogen and acetylene occur occasionally in small quantities. Miners have given these gases the general term "damps." The different damps are known as white damp, black damp, stink damp, and afterdamp. The term afterdamp is applied to those gases produced by explosions and mine fires. The chemical names, however, are more scientific and better because the popular names are not given by all miners to the same gases. Smoke and dust also occur frequently in mine air. Finally, aside from smoke and dust and the presence of abnormal gases or lack of oxygen, changes in the temperature, humidity, and air movement require consideration, because they may also produce disagreeable effects on man. Before taking up the study of the clinical cases, what is known concerning each of these conditions will be reviewed.

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DANGEROUS GASES

Carbon Monoxide

Carbon monoxide (CO), or white damp, is a colorless, odorless, tasteless gas, slightly lighter than air, but readily diffusing in air to make a homogeneous mixture. It is formed from the incomplete combustion of organic material. It occurs in mines when not enough air is present to complete the burning of materials that contain carbon, such as coal, dust, wood, and methane. It is produced by fires and explosions and by the use of powder for blasting. Mixed with air in percentages of about 15.5 it is also explosive.

Sayers and Yant (2) state:

> Chemically, the recognized primary action of poisoning is in the union of the carbon monoxide gas with the hemoglobin, thus depriving the hemoglobin of its normal function of combining with oxygen. This union in regard to gas volumes is similar to the normal one with oxygen, it is in either case molecule for molecule,—that is, the gas volume capacity of the hemoglobin is the same whether it be in combination with oxygen, carbon monoxide, or a mixture of oxygen and carbon monoxide. The union of hemoglobin with carbon monoxide is a great deal more stable than a similar union with oxygen, which readily comes off at reduced pressures. Also, the relative percentages or tensions of the two gases which

will exert an equal combining force are greatly different, that of carbon monoxide being approximately 300 times that of oxygen or in a ratio of 300:1, which is termed the relative affinity of hemoglobin for carbon monoxide and oxygen.

In carbon monoxide poisoning it is not probable that complete equilibrium will be established, because as the amount of carbon monoxide hemoglobin formed increases, its tendency to dissociate into carbon monoxide and hemoglobin also increases, thus slowing down the reaction which at first proceeded rapidly.

. . . . With increasing concentrations of carbon monoxide, the time required for a given amount of hemoglobin to combine with carbon monoxide would decrease very rapidly, until with 1.0 per cent it may require only time enough to take a few breaths to produce a saturation of 60 to 80 per cent, which is fatal. Roughly, for a person at rest, it can be assumed that 80 per cent of the equilibrium values is attained after the following periods of time.

Concentration of CO in Air (incl.)	*Blood Saturation*[1] *%*	*Time hrs.*
0.02–0.03	23–30	5–6
0.04–0.06	36–44	4–5
0.07–0.10	47–53	3–4
0.11–0.15	55–60	$1\frac{1}{2}$–3
0.16–0.20	61–64	1–$1\frac{1}{2}$
0.20–0.30	64–68	$\frac{1}{2}$–$\frac{3}{4}$
0.30–0.50	68–73	20–30[2]
0.50–1.00	73–76	2–15[2]

[1] Eighty per cent. of approximate equilibrium values.

[2] Minutes.

As the amount of carbon monoxide absorbed by the blood is directly proportional to the amount of air breathed, the rate of saturation will be increased by anything that increases the rate of respiratory exchange. Thus, a man doing moderate exercise will breathe about twice as much air as a man at rest, and his blood will absorb carbon monoxide about twice as fast, while a man doing very strenuous work will breathe three or four times as much air as when at rest and his blood will absorb carbon monoxide in proportion to this increased breathing. High temperatures and high humidity also increase respiration and pulse and so increase the rate of absorption of carbon monoxide by the blood. Finally, atmospheres containing less than 20.9 per cent. of oxygen also increase lung ventilation and the rate of absorption.

The chemical reaction of carbon monoxide and hemoglobin, whereby oxygen hemoglobin is displaced and carbon monoxide hemoglobin formed, fortunately is easily reversible. The tendency is first to establish an equilibrium between carbon monoxide hemoglobin and oxygen hemoglobin and the reaction can then be made to proceed in either direction by changing the mass or tension of the gases in the pulmonary air. This fact accounts for the elimination of carbon monoxide on removal of the victim to pure air and it is upon this basis that the treatment advised is effective. As a result of their experiments, these investigators (3) have worked out curves comparing the elimination of carbon monoxide resulting from different forms of treatment. These are also of value in making fair estimates of the time required for the removal of carbon monoxide from the blood, should the saturation at any time be known. Thus, with 80 per cent. saturation and with no treatment except removal to pure air, it is estimated that the gas is eliminated in about eleven hours.

Haldane (4) (5), in 1895, showed that carbon monoxide was an entirely indifferent gas with no direct poisonous,

corrosive, or irritating effects on any of the tissues and that its entire physiologic effect was the result of its power to combine with hemoglobin. It has been known for many years that plants and insects which do not have hemoglobin are essentially unaffected by its presence even in very high concentrations. More recently Haggard (6), using the method of tissue culture, has grown brain cells as profusely in an atmosphere of 79 per cent. carbon monoxide and 21 per cent. oxygen, as in an atmosphere of normal air. In 1915 Emrys-Roberts (7) called attention to the fact that in uncomplicated carbon monoxide poisoning pulmonary symptoms never develop, and that when they do occur they are always due to other irritating gases, the most common of which is smoke.

As the result of these and numerous other studies (8) (9) it is now generally accepted that the primary physiologic action of carbon monoxide poisoning is entirely one of anoxemia, or oxygen want. In an exposure to carbon monoxide, the victim's blood is being continually and increasingly incapacitated for carrying oxygen from the lungs to the tissues, the degree of incapacitation depending upon the concentration of the gas and the duration of the period of inhalation. The severeness of the effects also depends upon the extent of the incapacitation and its duration. Long exposures to a low concentration will produce much more serious effects than short exposures to a high concentration, even though the percentage of hemoglobin combining with carbon monoxide is the same in each case. This is obviously due to the longer time that the body tissues are deprived of oxygen. As the effects are almost in direct proportion to the length of time and the extent of oxygen deprivation, whether the time elapses during exposure or after exposure, Haggard and Henderson (10) were able to formulate the following standard for exposure to carbon monoxide which estimates within reasonable limits the probable effect of a given concentration of gas in a given time:

> Multiply the time of exposure in hours by the concentration of the gas in parts per 10,000 of air. If the product equals 3 or less there is no appreciable physiologic effect. If it equals 6, there is sometimes slight malaise. If it equals 9, a headache with some nausea is produced in most people. If it equals 15, the conditions are dangerous for anything beyond brief exposure. If it is more than 15, they are extremely dangerous even for brief exposure.

The classic symptoms of carbon monoxide poisoning in about the order of their appearance and frequency are tightness across the forehead, headache, throbbing in the temples, weariness, weakness, dizziness, nausea, vomiting, loss of strength and muscular control, confusion, increased pulse and respiration, syncope, and collapse. Following these there is coma, usually with intermittent convulsions and Cheyne-Stokes' respiration, and finally death from respiratory failure. Sayers and Yant(2) divide these symptoms into two stages, depending on the response of the central nervous system. The first stage results from stimulation and begins with normal and ends in syncope. The second stage results from paralysis and begins with syncope, extends through coma, and ends in apnea. There are, of course, marked individual variations and sus-

ceptibilities and it is seldom that all of these symptoms are experienced by the same person. A person at rest may pass into the stage of dizziness and unconsciousness without experiencing any appreciable effects.

Other things being equal, the symptoms of carbon monoxide poisoning depend primarily on the degree of blood saturation. The predominating symptoms accompanying the various percentages of blood saturation, as given by Sayers and Yant (2), are shown in Table 1.

With a given blood saturation the character and severity of the symptoms depend on the time required to attain that saturation and the degree of muscular activity. The number of symptoms decreases with the rate of saturation. With high concentrations and rapid poisoning, a person may pass to the stage of syncope and collapse without premonitory symptoms. On the other hand, if the saturation has been acquired by a long exposure, the symptoms and after effects will be a great deal more severe. Muscular activity increases the need for oxygen and the extent of deprivation. In this way exercise increases the number and accentuates the character of the symptoms during exposure and will bring out latent symptoms after exposure. Men at rest have been exposed to carbon monoxide all day without noticing any marked ill effects, but on walking home or exercising have experienced severe symptoms even to unconsciousness. Further, anything that lowers the physical fitness of a man, such as illness, disease, fatigue, exposure, or alcohol, exaggerates the effects. Pulmonary and cardiovascular diseases in particular seem to make men more susceptible.

TABLE 1.—SYMPTOMS CAUSED BY VARIOUS PERCENTAGES OF CARBON MONOXIDE IN THE BLOOD

BLOOD SATURATION	SYMPTOMS
%	
0–10	No symptoms.
10–20	Tightness across forehead; possibly slight headache; dilatation of cutaneous vessels.
20–30	Headache; throbbing in temples.
30–40	Severe headache; weakness; dizziness; dimness of vision; nausea and vomiting; collapse.
40–50	Same as previous item, with increased respiration and pulse and more possibility of syncope and collapse.
50–60	Syncope; increased respiration and pulse; coma; intermittent convulsions; Cheyne-Stokes' respirations.
60–70	Coma; intermittent convulsions; depressed heart and respirations; possibly death.
70–80	Weak pulse; retarded respirations; respiratory failure and death.

Chronic carbon monoxide poisoning results from repeated exposures to small amounts of the gas. It occurs most frequently in closed garages, about blast furnaces, and from leaky gas connections. It may occur in mines in the neighborhood of underground fires. The most prominent symptoms described are headache, giddiness, muscular weakness, palpitation, breathlessness, indigestion, fatigability, nervousness, and weakening or loss of the mental faculties.

These cases are better and more properly termed intermittent poisoning, as the time spent in normal air is practically always sufficient for the complete elimination of the retained gas. Furthermore, provided the daily dose is small, it would seem that their seriousness has been considerably overestimated. In the cases reported in the literature, the only definite finding has been diminished muscular power; practically all investigators (11) are agreed that it is very difficult to state how much of this is due to alcoholic and other excesses, unhygienic living, and venereal disease, and how much to the effects of the carbon monoxide. Haggard and Henderson (10) state that common sense and common experience, as well as thoroughly grounded scientific evidence, indicate that carbon monoxide is not an accumulating poison like lead, but is rather an asphyxiant like water, and that "taken occasionally and in small amounts it is almost as harmless." It has been repeatedly shown that both men and laboratory animals develop a distinct tolerance to the gas similar in all respects to that developed to high altitudes and accompanied, as is the latter, by the development of a polycythemia (11) (12). In both cases this seems to be an adaptive or conservative process on the part of the system whereby the harmful effects are mitigated and a greater tolerance established.

The pathologic changes accompanying or following carbon monoxide poisoning are the secondary results of the anoxemia it induces. For this reason, they are practically limited to cases of prolonged exposure where the degree of blood saturation has been sufficient to produce unconsciousness. They consist essentially in hyperemia, edema, hemorrhage, secondary ischemic degeneration, and finally fibrosis. The lesions usually appear as scattered foci and seem to result from thrombosis and degeneration of the walls of the smaller blood vessels. In fatal cases, where death has occurred during or shortly after exposure, the blood is usually a bright cherry red. There are, however, no other changes (13), and red cells which have taken up a considerable percentage of their capacity for carbon monoxide and have given it off are as good as before. While all tissues are likely to suffer sooner or later from anoxemia, their resistance, with the exception of the central nervous system, is such that structural damage does not occur, except perhaps in cases of fatal poisoning where the inhalation has been prolonged. On the other hand, the tissues of the central nervous system show a high susceptibility to permanent damage as a result of even temporary deprivation of oxygen. Even here the tissues show a marked difference in their nutritive requirements. Different groups of nerve cells show unlike ability to resist complete anemia without losing their ability to survive. Macleod (14) has summarized the existing knowledge by pointing out the varying periods of time beyond which anemia cannot be extended without producing changes in the nerve cells which place them beyond recovery. For the cerebrum, eight minutes may suffice; for the cerebellum, medullary centers, and spinal cord, thirteen, thirty, and sixty minutes, respectively. The great susceptibility of the cerebral cells to lack of oxygen explains

the ease with which consciousness is lost as a result of respiratory failure. (See also Greene (15).) It also accounts for the dulness, loss of discrimination, and the narcotic and anesthetic manifestation so frequently seen during exposure.

Examination of the nervous system in fatal cases usually shows hyperemia of the brain and its coverings. In conjunction with this excess of blood there is often an increase in the cerebrospinal fluid and more or less edema of the brain, which may be localized or general (16). In addition, there are usually punctiform hemorrhages of various sizes. Finally, in cases which have survived longer, there are ischemic changes with areas of degeneration (17). This latter change is so frequent in the lenticular nucleus, particularly its medial portion, the globus pallidus, that it has been described by Hill and Semerak (18) as a "characteristic lesion." It is usually bilateral. These investigators have also shown that the extent of these changes is materially influenced by the preexisting condition of the brain, particularly the integrity of its arteries. These changes account for the occasional mental defects which sometimes follow severe cases of poisoning. Peripheral nerve lesions have also been described (19), but are naturally much less frequent than those of central origin.

While fatal cases undoubtedly almost always show structural changes, depending on the amount of gas inhaled and the duration of life after inhalation, it does not follow that similar though less marked changes are even frequently present in cases that recover. It must be remembered that the time limits for survival of nerve cells quoted above are for complete anoxemia and that the anoxemia in carbon monoxide poisoning is never complete. Moreover, the known susceptibility of the cerebral cortex to anoxemia makes it possible to say that, in practically all cases where consciousness has not been lost, there have been no structural changes.

The after effects of carbon monoxide poisoning are not due to retention of the gas but are the results of the injury done to the tissues by the insufficiency of oxygen supplied to them during and immediately after the period of inhalation. They range from practically no effects to headaches, muscular pains, loss of strength, fatigue, long periods of unconsciousness, mental derangements such as dulness, apathy, loss of initiative or memory, and paralysis. The possibility and severity of these depend on the duration of oxygen deprivation, personal idiosyncrasy, and physical condition before exposure. It seems probable that much of this idiosyncrasy is due to previous health conditions and that many diseases such as cerebral arteriosclerosis, syphilis, and alcoholism are contributory to serious sequelae. Here again, however, the high susceptibility of the cerebral cortex to anoxemia makes it possible to say that an individual who has not been exposed sufficiently to produce unconsciousness will recover without permanent sequelae. This point is amply borne out by the experience of those investigators who, during the course of their experiments, have repeatedly allowed their blood to become highly saturated with carbon monoxide (3) (9) (20). As a result of his ex-

tensive investigations, Forbes (21) goes further and states: "In fact, if a young, healthy adult is severely gassed by 'white damp' or by blast furnace gas, he either dies in a few days or recovers entirely—a rule to which there are few exceptions." While severe poisoning is serious and often fatal, there is undoubtedly much unwarranted fear and hysteria regarding milder cases. On the other hand, some writers (22) have felt that exposure to carbon monoxide has a direct effect on the susceptibility of persons to acute respiratory infections, particularly pneumonia. Forbes was unable to confirm this. It would seem that the exhaustion, exposure, chilling, and lowering of the body temperature which so frequently accompany poisoning are the most prominent factors in such complications.

The diagnosis of carbon monoxide poisoning is usually made from a correlation of the history and the place of possible exposure with the symptoms produced. Such a procedure is necessarily subject to numerous errors because carbon monoxide may exist in unsuspected places, while the symptoms produced are common to many other causes. The only infallible test is examination of the blood for carbon monoxide hemoglobin. A method and an apparatus for this test have been developed by the United States Bureau of Mines (23). By its use, a small amount of blood (0.1 c.c.) can be quantitatively examined in a few minutes for carbon monoxide and a true diagnosis can be made. The same method may be used later to determine when the carbon monoxide has been removed. As carbon monoxide is rapidly eliminated from the blood, however, the method is valueless unless applied soon after the termination of exposure and is entirely useless in cases reporting hours later.

Recovery from carbon monoxide poisoning depends on the elimination of carbon monoxide from the blood. This begins as soon as the exposure is terminated and depends upon the mass action of oxygen. The rate of elimination depends on the percentage of oxygen in the air breathed and on the rate and depth of respiration. As the natural elimination of carbon monoxide by normal air is rather slow and does not attain the speed which is often necessary to save life or to reduce after effects, the practice in treatment is to give inhalations of oxygen in pure form, thereby increasing its tension both in the pulmonary air and in solution in the plasma and consequently hastening the elimination of carbon monoxide. Pure oxygen causes the elimination of carbon monoxide about four times as fast as normal air (3). This is the method of choice in the treatment of all ordinary cases. In cases where the initial saturation has reached the stage (usually above 40 per cent.) of respiratory failure, however, the respiratory factor becomes important, as during this period of feeble respiration the elimination will be slower. Here artificial respiration may have to be used and the inhalation of a mixture of oxygen with 5 per cent. of carbon dioxide is advantageous. As a rule, however, this period of feeble respiration is comparatively short and with normal respirations the elimination seems to be as good with pure oxygen as with the mixture of oxygen and carbon

dioxide (3) (24). Such inhalations should be continued for at least twenty to forty-five minutes, during which the victim should, of course, be kept quiet and warm. At the end of this time, experiments have shown that the gas is practically eliminated from the blood. Later, the patient should be treated as an ordinary convalescent and be given plenty of time to recuperate. After effects can only be treated symptomatically. Practically the die is cast for death, permanent defects, or recovery at the moment or shortly after the patient is brought out of the asphyxial atmosphere.

Carbon Dioxide

Carbon dioxide (CO_2) is a colorless, odorless, tasteless gas. In very small percentages it is a normal constituent of air. It is formed in mines as a result of fires, explosions, and blasting. It is also formed more slowly and steadily as a result of the action of air on the oxidizable material in coal, such as the sulphide of iron. Carbon dioxide is nonirritating and is in no way a protoplasmic poison. It is constantly formed in the body as a waste product of metabolism. It is, however, a physiologically active gas, as the normal control of respiration depends upon its tension in the arterial blood which circulates through the respiratory center in the medulla (25). Overaccumulation produces increased respiration.

The physiologic effects of abnormal amounts of carbon dioxide in the inspired air, then, are simply respiratory stimulation and oxygen deprivation. Carbon dioxide differs from carbon monoxide in that its action is immediate and ceases immediately when the victim enters normal air. The oxygen carrying powers of the blood are not interfered with, the condition being one of simple suffocation.

The effect of breathing 0.5 per cent. of carbon dioxide in air is a slight but almost unnoticeable increase in the ventilation of the lungs, about equivalent to that occurring on ordinary moving about. As the percentage increases, respiration is further stimulated until at between 5 and 7 per cent. there is distinct panting and at 10 per cent. respiration becomes very difficult and any but slight exertion extremely laborious (26) (27). There is also usually headache, throbbing in the temples, and general weakness. The effects of carbon dioxide are considerably increased if at the same time the percentage of oxygen in the air is reduced. This is usually the case in mines where it occurs mixed with nitrogen in the form of black damp.[1] Frequently in such cases there is also a narcotizing effect with lethargy and confusion.

Black damp is essentially a residual gas. It is not only formed as a result of fires and explosions but also tends to accumulate in large quantities where the atmosphere is motionless and the oxygen has been removed from the air by long contact with the coal, as in old, abandoned workings. Being heavier than air, it tends to accumulate in low places. Average black damp "contains 10 to 15 per cent carbon dioxide and 85 to 95 per cent nitrogen; the proportion of carbon dioxide is seldom more than 20 per

[1] Carbon dioxide is often called "black damp" by mining men but strictly speaking this term applies to a mixture of carbon dioxide and nitrogen.

cent or less than 5 per cent" (1, p. 13). A small amount of oxygen is usually though not always present. Of course when the air is in motion, black damp is readily diffused and diluted, but with a steady air current and few obstructions it may move as a layer along the airway for a considerable distance. It usually produces symptoms largely from lack of oxygen but also partly from the presence of carbon dioxide. These usually appear when the oxygen has fallen to between 12 and 15 per cent. It causes fatal accidents by suffocation.

Although sometimes carbon dioxide may be largely responsible for the effects produced by black damp mixtures, yet, with regard to the effects produced by black damp on lights, it is the lack of oxygen, not the presence of carbon dioxide, that makes the lights go out. The United States Bureau of Mines has found that the proportion of carbon dioxide in mine atmospheres in which lamps go out is seldom enough to affect the flame. An ordinary miner's lamp or safety lamp or an open torch goes out in an atmosphere containing about 17 per cent. of oxygen, while an acetylene lamp will not burn in air containing less than 12 per cent. of oxygen.

Slight diminution in the oxygen of the air is without effect on man. This is proved by the fact that men live and work 5,000 feet and even 10,000 feet above sea level. Haldane (1, p. 15) (28) states: "A diminution from 20.93 to 15 per cent oxygen by volume is practically without effect on man although, of course, a candle or wick-fed flame is instantly extinguished. As the decrease of oxygen proceeds further certain effects begin to be noticed, but a person not exerting himself will, as a rule, not notice anything unusual until the oxygen percentage has fallen to about 10 per cent. The breathing then becomes deeper and more frequent, the pulse more frequent, and the face somewhat dusky. From this to lower percentages the symptoms are more pronounced, and a person's life becomes in grave peril." These statements refer to persons at rest and in "fresh air." Exercise by increasing the demand for oxygen increases the effects and makes them manifest at higher percentages. They are also increased if the atmosphere is warm, moist, or still. Nevertheless, observation of even an acetylene flame will usually give ample warning of a dangerous drop in oxygen.

Methane

Methane (CH_4), marsh gas or fire damp, is a colorless, odorless, tasteless gas. It is formed when organic material decomposes in the absence of air and the presence of water. It is given off in varying quantities from the seams of coal and from the rocks above and below the coal, depending upon the individual seam, its depth below the surface, and the rate at which the workings are advanced. Methane is about one-half as heavy as air and so tends to accumulate in the high parts of workings and in the cavities of the roof. It will diffuse with air, however, and when once mixed will not again separate. Methane has no effect on the human system. Only rarely is it present in sufficient quantities to produce symptoms by reduction of the oxygen supply. If such a condition should arise and cause fainting, the individual would fall into

purer air and revive. It is dangerous only because it forms explosive mixtures with air. The explosive limits are usually given as between 5.5 and 13 per cent. Less than explosive proportions of the gas may, when mixed with dust and air, make these mixtures explosive.

Other Gases

The other gases found in coal mines are relatively unimportant because of their infrequency and because they are rarely present in sufficient quantities to produce appreciable effects.

The nitrogen oxides are produced when nitroglycerin or similar substances are used and when, on being exploded, they are not completely detonated so that a part burns slowly. Then, instead of the production of nitrogen and carbon dioxide, the nitrogen is given off in combination with oxygen. Nitric oxide (NO) is first formed, and usually rapidly oxidizes to nitrous oxide (NO_2). This again quickly reacts with water to form nitrous acid so that what is inhaled is mainly a mixture of the fumes of nitrous and nitric acids. According to Irvine (29), inhalation of more than small amounts of these fumes produces a characteristic sequence of symptoms. Immediately, there is slight irritation of the eyes, nose, and throat, and occasionally there is slight headache. These effects soon pass off and are followed by a latent period of four to eight hours. This is then followed by an acute inflammatory edema of the lungs which appears suddenly and develops rapidly. It is manifest by dyspnea, cyanosis, pain in the chest, cough, and a profuse watery and often bloody expectoration. Nitroglycerin is practically never used in coal mines, and therefore nitrous poisoning does not often occur.

Hydrogen sulphide (H_2S), or stink damp, is a colorless gas possessing the odor of rotten eggs. It is formed by the decomposition of sulphides in the presence of moisture. It is an irritant poison (30), probably active in concentrations of about 0.01 per cent. It produces conjunctivitis, pharyngitis, and bronchitis. In high concentrations it may act as an asphyxiant. Recovery is almost invariably rapid and complete.

Sulphur dioxide (SO_2) is formed in blasting. It is responsible for most of the acrid odor of powder smoke. It produces only local irritation.

With regard to acetylene, there is little, if any, chance of men being poisoned by its use in mines.

Smoke and Dust

Smoke produces irritation which results in conjunctivitis, coryza, pharyngitis, and bronchitis. The severity of these manifestations depends on the density and other qualities of the smoke and on the period of exposure. The effects are also increased by preexisting acute or chronic respiratory disease. Severe cases are occasionally followed by pneumonia. On the other hand, the effects are usually quite transient and in healthy individuals almost invariably clear up promptly.

Dust is also a recognized respiratory irritant. Its action is also transient, provided, of course, the exposure is not continued. While coal mining is usually classified as one of the dusty trades, coal dust and soot, in contrast to the other dusts, are relatively harm-

less. It has been an almost universal observation that coal miners are subject to less pulmonary disease than any other group of occupied males (31)(32)(33). In discussing exposure to dusts, Lord (31, p. 419) states that "The infrequency of pulmonary disease among coal-miners is a striking and significant exception which has been vaguely and unsatisfactorily ascribed to a protective influence from coal dust and soot." So striking and regular is this connection that even recently the inhalation of coal dust has been suggested again for the treatment of pulmonary disease (34). While the harmlessness of coal dust *per se* seems well established, it is more probable, however, that the relative freedom of miners from pulmonary disease is due to other factors than protection afforded by its inhalation. Their work is underground where the dampness, separation in rooms or entries, and the constant invasion of new territory prevent the spread of infected material. In addition, they are well paid and as a class are intelligent men with good home surroundings.

The steady inhalation of coal dust year in and year out has, perhaps, a slightly different aspect. There is no doubt that if a man works in a coal mine sufficiently long he will invariably develop pneumonokoniosis. Lord has shown, however, that the invasion of the lung by dust alone does not necessarily give rise to pulmonary disease, and that with regard to coal dust in particular there is little or no tissue reaction about the deposits. He concludes that there must be some additional factor and that this is bacterial infection. He states (31, p. 428) that "It is probable that most, if not all, cases classed as pneumonoconiosis are more properly placed under subacute or chronic pulmonary infections. The most important question in diagnosis is whether the pulmonary disturbance is due to infection with tubercle bacilli or other organisms."

Warm, Moist, and Still Air

The effects of high temperatures, high humidities, and lack of movement of the air on workers are almost a matter of everyday knowledge. In contrast to metal mines, however, the occurrence of hot air in coal mines is relatively uncommon, nor are the changes in humidity marked. The average temperature in the coal mines of Illinois is about 70°F. and with temperatures below 75°F. changes in humidity are of little importance.

On the other hand, lack of movement or stagnation of the air is more frequent and therefore more important. When there is very little or no movement of the air, that next to the body becomes warm, proper evaporation from the surface of the body is hindered, there is a rise in body temperature, and the ability to work is impaired. Obviously, as the temperature and humidity increase the results of deficient air movement also increase. Sayers and Harrington (27) (35), studying the effect of air movement, found that, if the air temperature is above 75°F. and the relative humidity high, the efficieney and comfort of the worker are materially increased by air movement. They state that, with a linear movement of 100 feet a minute, a miner is comfortable and fairly efficient so long as the temperature is not above 85° wet bulb. The same is

true when the temperature is between 85° and 90° provided the air velocity is 200 to 300 linear feet a minute. With a temperature of 90° to 95°, the air is very oppressive when still but is not especially so when it has a movement of 400 to 800 linear feet a minute. Stagnant air also becomes quickly vitiated by breathing, the burning of lights, the combustion of powder, and the liberation of carbon dioxide and methane from the mined coal. More oxygen is also absorbed by the coal when the air is still than when it is moving. This vitiation has a distinctly depressing effect and not only reduces the amount of work men can perform but also seems to impair their vitality and increase their tendency to colds and bronchitis, particularly if they are already the subject of pulmonary diseases (36).

Clinical Study

Diagnosis

The records of 145 men who alleged exposure to and disability from abnormalities in the air of the mines in which they worked were studied. Their classification, according to the diagnosis made, is shown in Table 2. This grouping is entirely clinical and, therefore, probably not entirely correct. No information was available from the mine superintendents or inspectors as to the actual condition of the air at the time of the alleged exposures, so that, in most instances, the stories of the men had to be taken at their face value. Many of the men were neither intelligent nor trained in the matter of ordinary observation and could give but few data upon which to base an opinion. Not a few appeared for examination with fixed ideas concerning their condition and were either unable or unwilling to detail more than their conclusions.

TABLE 2.—DIAGNOSIS IN CASES ALLEGING "BAD AIR"

DIAGNOSIS	NUMBER OF CASES	PERCENTAGE
Carbon monoxide poisoning	30	20.7
Effects of work in stagnant air	32	22.1
Exposure to "black damp" (carbon dioxide and nitrogen)	6	4.1
Exposure to smoke	1	0.7
Disease	57	39.3
Undetermined—malingering?	19	13.1
Total	145	100.0

On the other hand, it is obviously impossible for a man who is affected by the air in which he is working to know just what is the matter with it or the character or the quantity of abnormal gases which may possibly be present. The presence or absence of air movement or of smoke were the only two factors concerning which one could be reasonably sure. Carbon monoxide may lurk in unsuspected places and may easily be confused with simple stagnant air or accumulations of nitrogen and carbon dioxide. Finally, the great majority of the men were seen at least several hours after leaving the mines so that tests for carbon monoxide hemoglobin, although made almost routinely, were of no practical value. In the more severe cases seen at the mine or hospital, either the apparatus for the test was

not available or oxygen treatment was given without waiting for its performance.

Carbon Monoxide.—In thirty cases, or about 20 per cent., the diagnosis of carbon monoxide poisoning was made. Cases 1, 2, 3, and 4 are typical illustrations.

Case 1.—Jacob B. There was a severe dust explosion in his section of the mine about 7 o'clock the night before, which broke down several of the doors and curtains so that the subsequent circulation of air was poor. The next morning, by the time he reached his room, he noticed that he did not feel right. When he began to work he developed headache, shortness of breath, dizziness, and weakness. The men about him were similarly affected and several had to be helped out. Subsequently, he went back through this section hunting for men who might have been overcome. He was exposed about four hours and when he came out was very weak with rapid, shallow respirations and a thready pulse. His cheeks and mucosae seemed unusually red. In about an hour, he was breathing normally but had headache, vertigo, and weakness on exertion. He was back at work in a week.

This was obviously an exposure to the after gases from the explosion, the most dangerous constituent of which is carbon monoxide. Over 100 men worked in this section and all were similarly but less severely affected. None were unconscious. About seventy-five reported to the mine office for examination. Only twelve were sufficiently disturbed to desire or require hospital care. Two of these had acute coryza and one an old rheumatic mitral endocarditis. Four other men were admitted to the hospital during the next few days. One of these had an acute sinusitis, the result of a head cold, which developed the day after his exposure. None remained in the hospital more than a week.

Case 2.—J. M. C., shot firer. As one of the shots went off, the whole entryway seemed to catch fire. He dodged into one of the rooms and waited until the fire went down and back. He then came out and walked to the cut-off, where he lay down. The air was very hot, stagnant, and smoky. After about fifteen minutes he lost consciousness. It was approximately an hour before he was found. When brought up he was very cold and pale with a rapid pulse and rapid, shallow respirations. He received no treatment except external heat and fresh air. In a half hour he could be roused, and in an hour he was entirely conscious and complained only of headache and dizziness on moving. He remained in the hospital a week and returned to work in four weeks. His unconsciousness came on gradually as is characteristic of carbon monoxide poisoning. Evidently this was quite a severe exposure. Although his nose, mouth, and throat contained much soot-like material, he complained of irritative symptoms for only two days.

Case 3.—Wm. H. About two months ago, he developed a severe throbbing headache about two hours after starting to work. He attributed this to the air. The headache cleared up a few hours after he left the mine and did not recur. This morning he felt well on going to work but after reaching his room noticed a queer odor to the air. After loading one car he noticed headache, heaviness through his chest, dizziness, and weakness. The man in the next room came in and said that the air was bad and advised him to quit. He started to load another car but became very dizzy and faint, staggered to the parting and fell unconscious. In the mine office he quit breathing twice and artificial respiration had to be applied. When seen about a half hour later, his color was good, his pulse rapid, and his respirations were very rapid and shallow. His condition improved rapidly and by the time he reached the hospital his respirations were normal and he felt well except for extreme headache.

He left the hospital in a week. Subsequently, he complained of weakness, nervousness, and fatigability. He returned to work in ten weeks. The slow but steady increase in symptoms is characteristic of a rising saturation with carbon monoxide. The increased exertion, when he finally decided to get out, increased the oxygen deprivation to the point of syncope and collapse.

Case 4.—Andy M. For the last three months the air in his room had often been stagnant and on these days he had tired easily and usually developed headache. On five or six occasions, although the movement of the air had seemed better, he developed weakness in the pit of his stomach, throbbing headache, palpitation, rapid heart action, shortness of breath, and nausea and he had to quit. On one of these occasions the men in the rooms on either side of him collapsed. He always felt all right the next day or the day after. For the last two weeks, he had felt perfectly well and the air seemed good. On starting to work this morning the air seemed about as usual but after loading one car his old symptoms recurred and he soon became so weak that he was barely able to reach the bottom. When seen four hours later his examination was negative except that he still became short of breath on exertion. The test for carbon monoxide hemoglobin was negative. He returned to work in five days.

Of these thirty men only five were rendered unconscious. The period of disability was known in eighteen cases and averaged six weeks. None showed any sequelae attributable to their exposure, though all complained of weakness and fatigability, and many of nervousness and headache during their period of convalescence. Ten of the men returned at intervals of one to several months claiming persistent symptoms. The findings in these cases were: sinusitis, 2; rheumatic endocarditis, 1; diabetes, 1; pleurisy, 1; hypertensive arteriosclerosis and chronic spondylitis, 1; alcoholic neuritis, 1; neurosyphilis, 1; anxiety neurosis, 2. The neurotic cases were relatively simple in that the only factor seemed to be dread of another exposure. The men were all right out of the mine but on their return would develop nervousness, shakiness, and weakness.

Stagnant Air.—In thirty-two of the cases, or about 22 per cent., the men's complaints seemed attributable to simple stagnant air. In these cases it is impossible to say that abnormal gases might not have been present and a factor in their condition. Cases 5, 6, and 7 are illustrative.

Case 5.—John S. A week ago, one of the doors near his room was broken and since then the air at the face had been very still and oppressive. This morning there was practically no movement and after about an hour he developed headache, then weakness, and finally dizziness, nausea, and pains in his legs. He quit and walked out, a distance of about a mile and a half. The door was repaired a few days later and he was able to work satisfactorily.

Case 6.—Chas. H. In the late afternoon, there were two cave-ins in the main air course which nearly closed it. About four hours later, he was sent in with some other men to clean them out. The first cave-in was removed without difficulty; the second gave more trouble and he crawled through a small hole near the roof to work on the other side. In a little while he became faint and dizzy and then very weak. He was able to crawl back to the other side and, after sitting around for a while, he felt able to continue at work.

Case 7.—Anton A. For about eight weeks, the air in his room had felt still and heavy. In the mornings it had frequently been slightly smoky and smelled of powder. As he worked he usually developed headache, weakness, backache, and frequently shakiness in his legs. At first he was completely relieved by sitting in the main entry a short time, but for three weeks it had taken two or three hours in

the open air for them to clear up. For the last few days he had had no appetite and had felt tired all the time. Examination and carbon monoxide test were negative. The red cell count was 6,350,000. This increase in the red cells is probably compensatory to the prolonged oxygen deprivation. Complete cytologic examinations were made in nearly two-thirds of all the cases and revealed nothing of significance except in this case and one very similar to it.

The disability in twenty of these cases was known and averaged a little over one week. Six of the cases were complicated by acute upper respiratory infections and if these are excluded the disability averaged only a few days. As already mentioned, it seems probable that stagnant air increases the susceptibility to acute respiratory infections.

Carbon Dioxide and Nitrogen.—Six cases, or about 4 per cent., were attributed to accumulations of carbon dioxide and nitrogen. The following (Cases 8, 9, and 10) are illustrative:

Case 8.—Joseph H. He was found unconscious in his room about 10 in the morning. As soon as he reached fresh air, he revived, and when seen about half an hour later he felt well except that he was a "little scared." He stated that for six weeks the air in his room was often still and that working caused headache and weakness which cleared up as soon as he got out. He felt fine on going to work that morning. After he started work he remembered becoming dizzy and short of breath but nothing else. The men in the rooms next to him were not affected. He returned to work in three days. The panting and sudden onset and quick clearing up of unconsciousness are quite characteristic of simple oxygen deprivation or suffocation.

Case 9.—Ted S. For two weeks he had been working about 60 or 70 feet ahead of his crosscut and noticed that the air was stagnant and that he frequently had slight headache while working. This morning, as soon as he reached the face, he noticed weakness and shortness of breath. The latter increased and before he could do anything his legs collapsed and he fell. He remembered calling but did not remember being removed from his room. He revived at once and by the time he reached the ground felt practically all right. He returned to work two days later.

Case 10.—John J., driver at night. On the night in question, the air in his section seemed a little still and smoky but did not affect him. At the bottom of a small depression called the "biscuit hole," his mule stumbled and then laid down. He tried to pull him up but noticed he was faint and panting. He started to run out but fell and had to crawl to higher ground. He had to be helped out, had severe headache, and vomited. In an hour he felt very much better except for an irritated throat and a cough. He slept on one of the benches in the washhouse and awoke feeling very cold. Subsequently, he developed a severe bronchitis, probably due mainly to his exposure while asleep, though the smoke may have been a factor, and he was unable to work for twelve weeks. A localized accumulation of black damp in a low place in a corridor when the air circulation was slow was probably responsible.

Smoke and Dust.—In only one case (Case 11) did smoke seem to be the chief factor in the production of disability.

Case 11.—John F. While firing shots there was a dust explosion in one of the sections near the bottom of the shaft. In coming out he had to walk about 2 miles through hot, smoky air. By the time he got out, his eyes, nose, mouth, and throat were burning intensely. The next morning he had a coryza, sore throat, and severe cough which was accompanied in a few days by rather profuse expectoration. His condition improved though when seen several weeks later he was still coughing. Examination revealed only a bilateral conjunctivitis and a red throat.

Only eighteen of the whole group of 145 men described smoke in the air

to which they were exposed. Of these only four complained of any irritative symptoms and in only two of these, Cases 10 and 11, were the manifestations of any importance.

Although coal mining is often classed as one of the dusty trades, no patients were seen who complained of dust.

Disease.—In fifty-seven cases, or about 39 per cent., various diseases were responsible for the men's condition. The diagnoses in these cases are shown in Table 3. They require little comment. In all of them the clinical picture was fully explained by the diseases found. In practically all of them, the symptoms antedated the alleged exposure. In none was there reason to feel that the possible exposure to abnormalities in the mine air had aggravated or altered the natural course of the disease found. Only about a third thought that the air in their working place was in any way abnormal. Only six complained of smoke and none of these presented any irritative symptoms. The great majority thought the air was bad simply because they became sick. They were able to start to work, became sick and had to quit: therefore the air must have been bad.

Undetermined (Malingering?).—Finally, there were nineteen cases, or about 13 per cent., referred for examination from two months to over a year after their alleged exposure in which nothing in the way of a diagnosis in regard to their original condition could be made. There is no more unsatisfactory case to see than an alleged "bad air" exposure which has occurred weeks or months previously and has been argued and perhaps tried many times. None of these men had been unconscious. Only three claimed to need assistance in getting out of the mine. Two who were past 60 showed a moderate degree of arteriosclerosis. None of the others showed any objective evidence of disease, nervousness, neurologic disorders, or disturbances in nutrition. There were no cases of memory defects, apathy, dispositional or personality

TABLE 3.—DISEASES ATTRIBUTED TO "BAD AIR"

Acute upper respiratory infections	14
Grip	5
Tonsillitis	3
Bronchitis	3
Sinusitis	2
Pleurisy	1
Arteriosclerosis	9
Without complications	4
With cerebral hemorrhage	3
With angina pectoris	2
Alcoholism	6
Chronic bronchitis	5
With sinusitis	2
With bronchiectasis	1
With pneumonitis	1
Without complications	1
Epilepsy	3
Pulmonary tuberculosis	3
Secondary anemia	3
Hemorrhoids	1
Epistaxis	1
Undetermined	1
Colitis	3
Neurosis (due to environmental factors unrelated to work)	2
Obstructing prostate	2
Exophthalmic goiter	2
Pyelitis	1
Carcinoma of the lung	1
Nephritis	1
Diabetes	1
Autumnal hay fever with asthma	1
Total	57

changes, etc., which could possibly be traced to any sort of exposure unaccompanied by loss of consciousness. Four of the cases came up following a prolonged strike and over half of the others in the fall following a summer of slack work. Whatever may have been their original condition, it seemed obvious at the time of their examination that they were exaggerating their disability if not frankly malingering.

Conclusions

1. The majority of men alleging disability from exposure to "bad air" in the mines are sick from diseases which are unrelated to their employment.

2. Simple stagnant air is the most common cause of complaint. It produces a very short period of disability.

3. Carbon monoxide is the next most common cause of disability. Exposures which do not cause loss of consciousness are practically never dangerous. The after effects are fatigability, weakness, headache, nervousness, and muscular soreness. Convalescence should be established in a few weeks. There are no sequelae. All so-called "late symptoms" are due to extraneous disease. Cases where the exposure has continued to syncope and collapse almost invariably recover entirely or die. It is probable that the late sequelae described in the literature are limited to those cases which have lived after a prolonged period of unconsciousness.

4. Stagnant, vitiated air seems to increase susceptibility to upper respiratory infection. On the other hand, such infections following carbon monoxide inhalation seem attributable to the physical exposure and chilling which frequently accompany it.

5. Cases of illness due to exposure to carbon dioxide and nitrogen are relatively uncommon. The condition is one of simple suffocation and when recovery takes place, it is rapid and complete.

6. Smoke is an uncommon cause of disability. Its irritative symptoms usually clear up rapidly. Dust does not seem to be a factor.

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A SIMPLE FACE MASK FOR CERTAIN TYPES OF DUSTY INDUSTRIAL PROCESSES*

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THERE are a large number of industrial processes which, while not technically dust hazards, are nevertheless associated with the production of sufficient dust to make some kind of protection desirable. Such processes are those connected with the production and packing of many kinds of dried soap; with the packing and handling of lint and other surgical dressings; and with the various stages in the production of powders of innumerable varieties.

In the general course of events the processes which the writer has in mind are not such as to call for the use of the standard respirators, yet they are sufficiently dusty to cause irritation of the nasal, buccal, and pharyngeal mucous membranes. The average worker ties a piece of gauze or bandage round the mouth and nose or else uses one of the simple forms of padded respirator. These appliances, however, are not only hot and uncomfortable but they are definitely to be condemned on the grounds of hygiene. They bear their share in the spread of infectious disease and they lead to the rebreathing of stale air.

In order to meet the need for an appliance which would cover the mouth and nose and while protecting them from dusty particles would yet be cool, clean, and light, the writer, in collaboration with Mr. J. Padgett of this Department, has devised the mask, shown in the accompanying illustrations, for use in processes which are dusty but not actual dust hazards. A wire frame is so made that any covering applied to it is held well clear of the nose and mouth, yet in such a way as not to impair the field of vision.

The covering may be varied to meet the needs of specific processes but for general use butter muslin is most serviceable. It may be used double or single. Whatever be the covering used, it is easily changed and in all cases a new cover should be used each day. The material in question is cheap and is readily procurable. One reason for frequently changing the material is that the small fluff on the muslin is essential to adequate filtration and with washing this fluff is destroyed.

The material is held to the mask by means of two small clips which are attached to the ends of the tapes which retain the whole appliance in position. These clips were made specially by Messrs. Chapman and Company, 53 Mostyn Road, Birmingham, England. The redundant material is tucked under the frame and/or into the top of the wearer's overall. It is impor-

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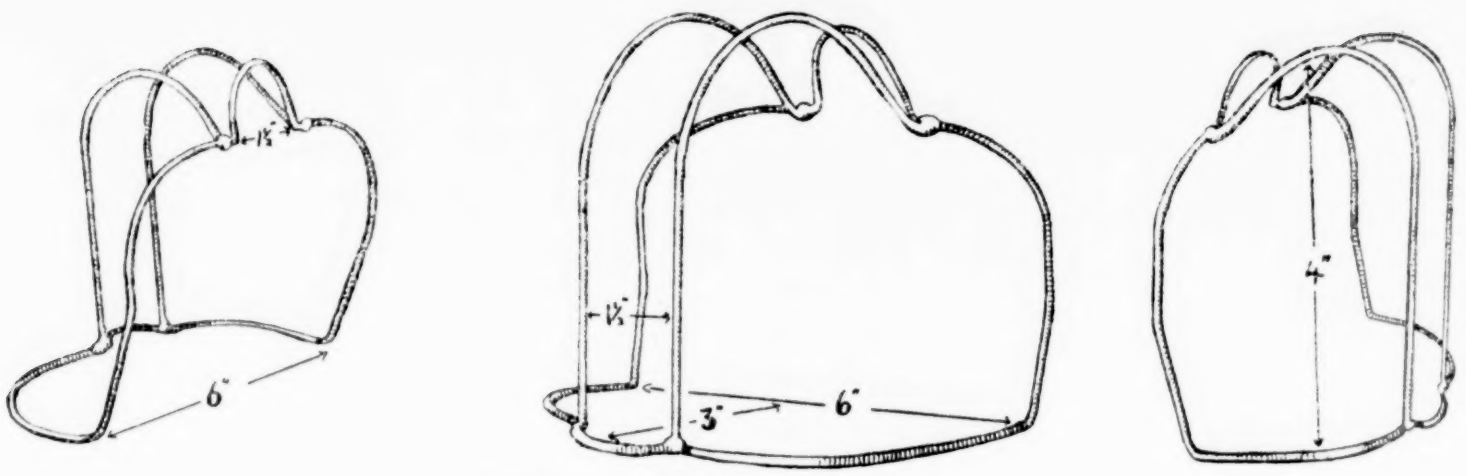
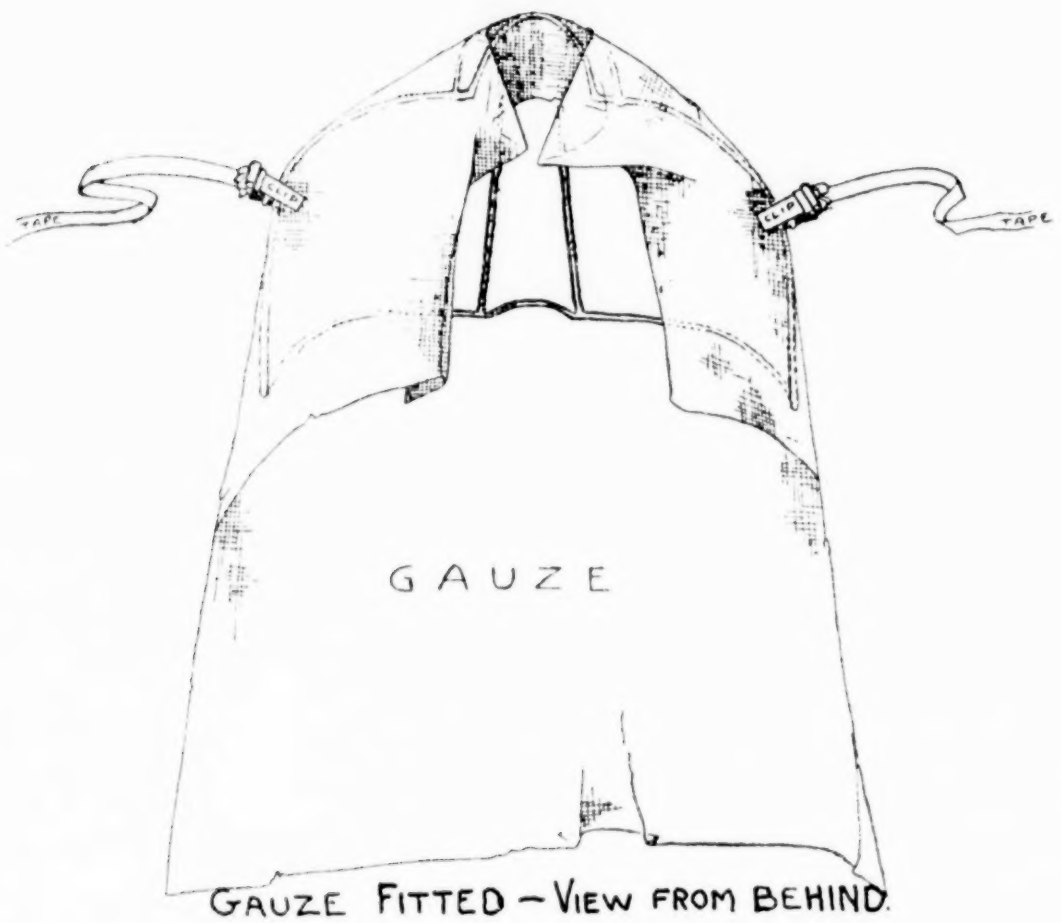


WIRE FRAME.



GAUZE FITTED — VIEW FROM BEHIND.

MASK IN POSITION.

tant to be sure that too much material is not turned in over the frame since in this way a large number of layers can easily be built up, thus rendering the mask unduly hot and uncomfortable. The clips slide easily on the frame and automatically take up the correct position so that the mask lies comfortably in front of the face.

In a mask of this nature very accurate facial fitting is not necessary since it must be clearly borne in mind that provided the nasal and pharyngeal irritation is abolished the aim has been attained.

The writer has found that this mask is entirely satisfactory when it is used intelligently, and the girl workers to whom it was offered have willingly adopted it without any compulsion whatever.

BOOK REVIEWS

DAS AUGE: SEINE SCHÄDIGUNGEN, IHRE VERHÜTUNG UND BEKÄMPFUNG. EIN RATGEBER FÜR LEHRER, ELTERN UND ERZIEHER. By Professor Dr. *Viktor Hanke*, Primararzt der Augenabteilung in der Krankenanstalt Rudolfstiftung, Wien. Paper. Pp. 128 with illustrations and index. Wien: Julius Springer, 1927.

This book was written in response to repeated demand for an informative work, intelligible to the layman, which should answer questions that arise in the minds of those—teachers, parents, educators—intrusted with the guidance of the coming generation. As its title indicates, the book specializes in vision, but it specializes in no other particular. The author's experience has given him an inclusive outlook upon those things that affect vision and lead to the deterioration and the loss of eyesight, and it would seem that he has successfully avoided one of the chief dangers of specialization, namely, an overemphasis of some narrow phase of the subject which may happen to lie within his special interest, and absorb time and space to the defeat of the broad purpose of the work.

As a necessary introduction, the book begins with a brief chapter on the anatomy of the eye, followed by one on its functions. The title of the third section is "Erblindung" which, to be in keeping with the contents of the section, would perhaps have to be translated "the impairment of vision," since it includes those conditions in which the capacity of the eye is more or less reduced without extinction to the point of helplessness. This section is subdivided to discuss the anatomic seat of the lesions, and their causes. The medical initiate would possibly assign to this section the caption "Pathologic Anatomy," but no such title appears.

These three introductory sections occupy some sixty-four pages—a little more than half the book, which is not too much. Necessarily, the accounts have had to be brief, and they have been made amazingly complete. The emphasis would naturally fall upon the acquired defects of vision, but the mention of congenital and inherited defects has not been omitted. Under the former (acquired defects) an extensive list is discussed: local infections, local disease of unknown cause (glaucoma, myopia, ulcers, retinal de-

tachment); eye complications of general diseases, noninfectious, nutritional, and infectious (general and local, acute and chronic); poisoning; and finally accidental injury.

These three sections, designed as an introduction to the main subject for the nonmedical reader, constitute a review which could well be read by physicians and surgeons, and seldom without profit; and the third of these sections may be looked upon as an announcement of the point of view from which the subsequent topics—with the possible exception of the last—will be treated.

The remaining five chapters are entitled: precautions for the prevention of visual defects, hygiene of the eye, the choice of occupation, occupational diseases of the eye, and, finally, schools for the visually defective.

It would be expected that in a work such as this, emanating from central Europe, myopia would occupy an important place, as it does, recurring again and again. On the other hand, if the writer's experience had been in America, muscular balance would no doubt have come in for a bigger share of the space than it does. As to myopia, one could well wish to see the general precautions against its aggravation during school years, as outlined by Dr. Hanke, applied widely both as special and as general hygienic measures: the maintenance of 30 cm. (12 inches) minimum reading distance in order to avoid convergence strain, an increase in the ratio of rest and recreation time to reading and writing time, the abolition of fine print (less than $1\frac{1}{2}$ mm. or $\frac{1}{16}$ inch letter height), the deletion of unnecessary eye work from school courses, and the provision of adequate, well-placed light.

His standards of light intensity are perhaps lower than those which are considered desirable in the United States and he considers bright sunlight too strong for prolonged exposure. But he is not afraid of light, decries the habitual wearing of protective glasses by normal persons as aimless, and harmful in the fact that the eyes become thereby unaccustomed to ordinary daylight. Protective glasses, simply enough, should be designed to meet two requirements: the agent from which the eyes are to be protected, and the requirements as to vision while they are worn—at least so much we gather from his discussion of them. Ultraviolet light need not concern us under usual natural and artificial light conditions. The long wave radiation from a light source that is too near leads to drying of the cornea and consequent irritation of the eyes, and to headache, and is therefore to be reduced; direct light from the source should not enter the eye.

It would seem that his recommended light intensities (p. 96) are somewhat low: 10 Meterkerzen for coarser work, 50 for finer. These are, however, brightness units, and represent the brightness of white paper under illuminations equal to the stated numbers of meter candles which would correspond to 0.84 and 4.2 foot candles, respectively. However, if we remember that the objects in the visual field have seldom the high reflection factor (80 per cent.) of white paper, and that 20 per cent. is neither uncommon nor low, 3.4 and 17 foot candles would perhaps in the average case give the stated brightness of field. These can

hardly be said to correspond to normal illumination or be the nearest approach to daylight—unless, indeed, we mean the daylight conditions commonly realized in industrial workplaces. It might be inferred from this that, industrially, daylight is as badly utilized in the author's land as it is here in America.

Space does not permit of discussion of the text in detail. It is not to be expected that a book of this size will go into extended medical discussions, nor does it propose to do so. It is, however, filled with good advice and warnings, and to the classes for which the book is designed—namely, parents, teachers, and educators—we would like to add: employers, company surgeons, labor leaders, and lawmakers.—*Percy W. Cobb.*

PREVENTIVE MEDICINE AND HYGIENE. By *Milton J. Rosenau*, Professor of Preventive Medicine and Hygiene, Harvard Medical School; Professor of Epidemiology, Harvard School of Public Health; Commander, M. C., U. S. Naval Reserve; Formerly Director of the School of Public Health of Harvard University and the Massachusetts Institute of Technology; Formerly Director of the Hygienic Laboratory, U. S. Public Health Service, etc. With chapters upon Mental Hygiene, by Abraham Myerson; Sewage and Garbage, by Gordon M. Fair; Vital Statistics, by John W. Trask; Statistical Methods, by Carl R. Doering; Conservation of Vision, by J. Herbert Waite. Fifth edition. Cloth. Pp. xxv, 1458 with index; illustrated. New York and London: D. Appleton & Co., 1927.

After a period of five years Dr. Rosenau has revised and partially rewritten his standard textbook, which is now issued in its fifth edition.

As is to be expected in a science in which rapid changes are taking place, several chapters appearing in former editions have been omitted and several other chapters have been rewritten. A section on mental hygiene by Dr. Abraham Myerson has been added.

The rather unique arrangement of chapters on the prevention of communicable diseases has been continued in this edition. These diseases are considered under five headings, each heading having a public health significance. The headings are:

1. Diseases having specific or special prophylactic measures.
2. Diseases spread largely through the alvine discharges.
3. Diseases spread largely through discharges from the mouth and nose.
4. Insect borne diseases.
5. Miscellaneous diseases.

Discussion of the diseases under the above headings is clear, concise, and practical. Methods of prevention are not only given clearly but even minutely, and the best method of handling a given situation is pointed out.

The second section of the book deals with mental hygiene. This section is written by Dr. Abraham Myerson. It deals with the present position of psychiatry and discusses mental hygiene at some length. The psychologic problems of childhood are particularly stressed and an indication of how psychoses should be met is suggested.

Section three, dealing with conservation of vision and ocular hygiene, written by Dr. J. Herbert Waite, covers these subjects briefly but adequately.

Section four attacks the broad problems of public health measures and methods. This section considers all the major activities of public health work and emphasizes important factors.

Section five deals with the effect which heredity has on the social problems of the community. The principles of heredity are sketched and the relation of heredity to certain diseases is discussed.

The next section, on food, takes up the danger of contaminated food and gives in detail the types of food most affected by bacterial decomposition through imperfect preservation as well as those affected by animal parasites. The caloric values of food are carefully presented.

Section seven deals with air, including the effect of its composition, pressure, humidity, and temperature on health. Following this light is discussed at length, the newer aspects of the effects of the different rays on the human body being given considerable space. Various forms of vitiation of the air such as smoke, dust, and fumes are described and their effect commented upon. The chapter on ventilation and heating covers the subject in an admirable way.

The two following sections are on soil and water. Under the first of these the nitrogen cycle and its relation to soil pollution, water purification, and sewage disposal is most entertainingly written and illustrated by charts. Soil and disease is next discussed, special attention being given to the animal parasites of man which may be spread by soil pollution. Water is considered from many angles. Sources of water, pollution and contamination, analysis, and microscopic examination are some of the subjects covered. In each case the public health aspect is brought out and the proper method of meeting a dangerous condition is given in detail.

The next sections, which cover sewage and refuse disposal, give the latest methods of handling these matters. Both chapters are by Gordon M. Fair; Dr. John W. Trask presents an interesting section on vital statistics.

Industrial hygiene and diseases of occupation are carefully reviewed and the subject considered from the economic as well as the public health angle. The individual symptoms, prevention, and treatment of a number of industrial poisons are given in detail and the whole scope of industrial medicine is rapidly but accurately reviewed.

The book closes with a section on school sanitation and child hygiene and one on the general topic of disinfection.

As a textbook for students and as a reference book for those doing any form of public health work, Dr. Rosenau's book will prove a dependable authority.—*W. Irving Clark.*